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ANNUAL REPORT ON LONG-TERM DOSE-RESPONSE STUDIES OF INHALED OR INJECTED RADIONUCLIDES

1990 - 1991

by the Staff of the
Inhalation Toxicology Research Institute
and the
Radiobiology Division,
University of Utah School of Medicine

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INHALATION TOXICOLOGY RESEARCH INSTITUTE
LOVELACE BIOMEDICAL & ENVIRONMENTAL RESEARCH INSTITUTE
P.O. Box 5890 Albuquerque, NM 87185

PREPARED FOR THE OFFICE OF HEALTH
AND ENVIRONMENTAL RESEARCH
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OCTOBER 1, 1990 through SEPTEMBER 30, 1991

by the
Staff of the
Inhalation Toxicology Research Institute
J. L. Mauderly, Director
and
Radiobiology Division, University of Utah School of Medicine
R. A. Daynes, Director

Editors
B. B. Boecker
B. A. Muggenburg
S. C. Miller
P. L. Bradley

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FOREWORD

My colleagues and I are pleased to present the third annual report focussed specifically on the life-span dose-response studies being conducted at the Inhalation Toxicology Research Institute, ITRI, and the University of Utah. As previous readers of regular ITRI annual reports may recall, progress on these life-span studies used to be included in those reports along with other research reports. Because of the importance and magnitude of these studies and the results coming from them, we decided to publish the scientific accomplishments and associated detailed charts and tables in a separate document.

The information presented here provides a complete summary status of these studies as of September 30, 1991. This report has been prepared as a stand-alone document for informational purposes. References to previously published documents and open-literature are also provided to assist the interested reader in obtaining additional information in specific areas.

The inclusion of results from both the ITRI and University of Utah studies in this report reflects the cooperative effort between investigators at these two organizations currently being supported under DOE Contract No. DE-AC04-76EV01013. Included in this arrangement is the provision of clinical care and biomedical observations for the dogs during the remainder of their lives. In a similar way, all of the living dogs in the life-span studies of Beagles irradiated chronically with gamma radiation at Argonne National Laboratory were transferred to ITRI on January 23, 1991 for clinical care and biomedical observations for the remainder of their lives.

An increasing number of the ITRI and University of Utah studies have arrived at the point where all dogs on study have died. Thus, our efforts are increasingly directed toward detailed reviews and analyses of study materials and data and the publication of these results in the open scientific literature. These completion efforts are being conducted by teams of investigators at both institutions. Their goals are to prepare basic manuscripts on each study, make analyses across studies within ITRI or the University of Utah programs, and other cross-cutting analyses among results from other laboratories, and use this information to derive the health risk implications of these studies for human subjects. An Executive Summary is provided to allow the reader to obtain a brief summary of the past year's progress and accomplishments and to serve as an indicator of the kind and location of information that is available in greater detail in the report.

Joe L. Mauderly, D.V.M.
Director

EXECUTIVE SUMMARY

This report, which covers the period October 1, 1990, through September 30, 1991, describes the scientific progress in, and current status of, life-span studies on the long-term health risks of chronic irradiation of Beagle dogs from internally deposited radionuclides or an external gamma source. Primary emphasis is placed on the 19 major studies that were initiated at the Inhalation Toxicology Research Institute, ITRI, and are now being completed. In addition, information is provided on life-span studies initiated at the University of Utah.

All living dogs in the Utah-initiated studies were transferred to the ITRI facility for the remainder of their life-span observations and measurements in September 1987. After this transfer, scientists at both institutions have worked collaboratively to ensure the orderly and thorough completion of these studies. This report is the third in a series of annual reports dealing with the current status and progress of both the Utah and ITRI studies.

Other life-span studies involving dogs exposed to gamma radiation from an external source were initiated and conducted for many years at Argonne National Laboratory, ANL. In 1991, the decision was made to discontinue the chronic irradiation of the remaining living dogs and to transfer all remaining dogs to ITRI for care, clinical observations, and pathological observations at death or euthanasia. This report also provides the current status of these dogs.

The sections dealing with the Utah and ITRI studies comprise most of this report. The information on both sets of studies is organized along similar lines, addressing basic research approaches, study designs, recent accomplishments, and progress in study-completion activities.

The ITRI-related section presents brief statements of project objectives, the general procedures used in these studies, and some study-specific features for each of the 19 studies being conducted with either beta- or alpha-emitting radionuclides. Dose- and effect-modifying factors being addressed in these studies include total dose, dose rate, LET, solubility, non-uniformity of dose, species, age, sex, health status, and mode of exposure. Recent additions to experimental protocols for studies in which dogs are still alive involve the collection and analysis of tumor tissues using currently available molecular biology techniques.

The ITRI section continues with a presentation on the current status of these studies divided into four sections dealing with a) studies in which dogs are alive, b) studies in which all dogs are dead, c) current activities related to completion of all these studies, and d) recent research accomplishments. At the beginning of this fiscal year, there were 131 dogs alive in 8 studies. By September 30, 1991, the closing date for this report, there were 106 dogs alive in 6 studies. With the exception of one dog exposed to ^{144}Ce in fused aluminosilicate particles, FAP, when 3 months old, all of the other living dogs received one or repeated inhalation exposures to monodisperse aerosols of $^{239}PuO_2$. Brief clinical and pathology summaries are given for each dog that died during the past year. For studies in which all dogs are dead, summary information and references to all previous reports on these studies in previous annual reports are given.

Many current activities in the ITRI program are directed to completion of the clinical pathology reviews of the dogs by study, data analyses, and manuscript preparations needed to determine and present the basic results of these studies and their implications for human health risks from inhaled radionuclides.

Eight brief reports are included that describe current results from these studies. The first two involve lifetime biological effects seen in Beagle dogs that were exposed once, by inhalation, to ^{91}Y in a relatively soluble form, $^{91}YCl_3$, or in a relatively insoluble form, ^{91}Y FAP. When inhaled in this relatively insoluble form, the lung and tracheobronchial lymph nodes received most of the chronic dose of beta radiation. Pulmonary carcinomas were the principal finding in dogs that died at long times after the inhalation exposure. The dose-response data were analyzed by using a proportional hazards model. The risk factor for chronic beta radiation from this study was about 1/2 that seen for lung cancer in Japanese A-bomb survivors exposed at 25 yr of age. The reduced risk factor may be due to the differences in dose rate in these two different exposure regimens.

In dogs that inhaled $^{91}YCl_3$, the ^{91}Y was absorbed from the lung and deposited in other organs, particularly the liver and skeleton. Six lung cancers and three cancers of the nasal cavity were observed. No skeletal cancers and only one liver cancer were found. These results make an interesting contrast to the results above for ^{91}Y FAP, showing how radionuclide form can influence which organs are at risk after an inhalation exposure.

The next report presents the late-occurring effects from inhaled $^{238}PuO_2$. If inhaled $^{238}PuO_2$ behaved in the same manner as inhaled $^{239}PuO_2$, it would be expected that the ^{238}Pu would be very insoluble, remain in the lung, and produce its long-term biological effects there. However, enhanced dissolution due to particle fragmentation, led to substantial long-term translocation of ^{238}Pu from the lung to liver and skeleton. Late-occurring cancers were seen in all three organs. These results emphasize the importance of having direct knowledge on the *in-vivo* solubility of an inhaled material as it may affect the lifetime health risks.

A study of the health effects of repeated inhalation exposures to $^{239}PuO_2$ is reported next. Dogs were exposed by inhalation to $^{239}PuO_2$ once, or once every 6 mo for 10 yr and observed over their life-spans. Preliminary analyses presented in this report indicate that the survival of animals dying from lung cancer appears to be independent of dose rate and dependent only on the total cumulative radiation dose to lung.

The next report presents a brief interspecies comparison of the risks of lung cancer from chronic beta radiation. A proportional hazards model was used to analyze and compare results for mice, rats, and dogs that inhaled a relatively insoluble form of ^{144}Ce. Similar lifetime risk factors were found in all species, increasing our confidence that the mean lifetime lung cancer risk factor, 70 lung cancers/10^4 Gy, could be used directly as an estimate for a lung cancer risk factor in humans for chronic beta irradiation.

A similar type of approach is described in the next report, which compares lung cancer risk factors for an alpha emitter, ^{239}Pu, and a beta emitter when inhaled in relatively insoluble forms by rats and dogs. The relative effectiveness factors for lung cancer produced by chronic alpha radiation compared to chronic beta radiation were 25 for rats and 36 for dogs. These results indicate that the use of a radiation weighing factor of 20 is only generally consistent with results seen *in vivo*.

Another comparison of the effects of chronic alpha versus chronic beta radiation is given in the next report using results for bone cancers seen in dogs that inhaled $^{90}SrCl_2$ or $^{238}PuO_2$. The ^{238}Pu induced primary bone tumors that were 97% osteosarcomas, primarily of the vertebra, pelvis and humerus. In contrast, the ^{90}Sr produced both osteosarcomas and hemangiosarcomas, primarily in the skull, rib, pelvis, and scapula. It is likely that these results reflect differences in patterns of radionuclide distribution and retention and the resulting doses received by critical cells.

The last report discusses the effects of age and antigen exposure on *in vitro* production of tumor necrosis factor in the dog. These studies involved 11 aged and 12 young Beagle dogs. Primary antigen instillation caused a more pronounced refractory effect in pulmonary alveolar macrophages, PAM, from young dogs than from aged dogs. These results suggest that the state of activation of PAM plays an important role in the diminished immune response seen in the lungs of aged dogs.

The current status and recent progress of life-span studies from the University of Utah begin the next major section of this annual report. These studies were initiated in the early 1950's for the purpose of determining the radiotoxicity of ^{239}Pu relative to that of ^{226}Ra for comparison with results obtained in humans containing burdens of ^{226}Ra. A number of studies with other radionuclides, primarily alpha emitters, were added in later years.

A brief presentation of the specific objectives of these studies is given, followed by a description of the general procedures. The main difference between the Utah studies and the ITRI studies is the exposure route. All of the Utah studies involve exposure by a single intravenous injection (or repeated injections for ^{224}Ra), whereas all the ITRI exposures, except for $^{137}CsCl$, were given by single or repeated inhalation exposures. The Utah studies involved both life-span studies and special serial-sacrifice studies. Of primary interest at the present time

is completion of the life-span studies. Study-specific features are presented for studies of young-adult Beagles that received intravenous injections of 1 of 10 different radionuclides or of immature or aged Beagle dogs injected with ^{239}Pu or ^{226}Ra.

Twenty two dogs died during FY-1991. By September 30, 1991, there were 39 dogs alive in the Utah studies at ITRI. These living dogs had been injected with ^{224}Ra, ^{226}Ra, or ^{239}Pu. The number of living dogs represents about 3% of the total population of life-span study dogs.

Research efforts in the Utah studies fall into three general categories: 1) continued care and observation of the dogs still alive, 2) detailed dosimetric studies, at the organ and local levels, of these injected radionuclides and the factors that influence these dose patterns, and 3) completion of final reviews of biological materials and data, compilations and analyses of data, and preparation of final study reports for publication in the open, scientific literature.

Care and study of the dogs on study are continuing at the ITRI facility. Most of the scientific effort at the University of Utah is currently being directed to completion of major life-span studies and the associated dosimetry studies required to determine dose-response relationships and estimated health risks for humans. The current focus of study completion activities is directed primarily to the studies of young adults dogs injected intravenously with either ^{226}Ra or ^{239}Pu. Milestone schedules are given for the various segments of these studies that need to be completed prior to completion of overall summary manuscripts on these studies. These individual milestone activities are also leading to other manuscripts that present more detailed examinations of the various dose and effect results obtained as well as analyses that cut across two or more studies.

Examples of recent progress in the completion of the Utah studies are given in five brief reports. The first two of these deal with soft-tissue effects seen in dogs injected with ^{226}Ra. The first report examines the occurrence of tumors in the eyes of dogs and compares these results with those from control dogs or dogs injected with ^{90}Sr. Excess melanomas occurred in the eyes of ^{226}Ra-injected dogs as a result of localized deposition of ^{226}Ra. No intraocular tumors in excess of those seen in control dogs occurred in the ^{90}Sr-injected dogs.

The second report deals with mammary tumors in dogs injected with ^{226}Ra. The issue of mammary tumors possibly arising from internally deposited ^{226}Ra arises from the increased incidence of mammary cancer seen in women exposed to ^{226}Ra while painting luminous dials. The occurrence of mammary tumors was examined in the population of dogs injected with ^{226}Ra and followed for lifetime observation. The analyses reported here indicate that the occurrence of mammary tumors in the Ra-exposed dogs was similar to that seen in the control dogs, but the age at tumor diagnosis was much younger in the Ra-exposed dogs than in the control dogs. The reasons for this difference remain to be determined.

The third and fourth reports deal with dosimetric factors for alpha emitters in the skeleton. In the third paper, the distribution of ^{226}Ra is compared for cortical and trabecular bones in humans and Beagle dogs. These analyses indicated that although the overall levels of ^{226}Ra retention in dogs and humans differ widely, the partitioning between cortical and trabecular bone may be quite similar. This information is a necessary ingredient in the extrapolations of bone tumor risk factors between dogs and people.

The fourth report discusses hit factors and other microdosimetric parameters for nuclei of bone-lining cells irradiated by alpha emitters. Values given for ^{237}Np, ^{226}Ra, ^{239}Pu, and ^{241}Am are additional pieces of information needed eventually to understand the relationships between average dose to the skeleton, local doses to individual bones, skeletal microdosimetry, and the resulting risks of radionuclide-induced bone cancer.

The final Utah-based report presents results of a study on the promotion of radiation-induced liver neoplasia by chronic ingestion of ethanol. Eight dogs injected with ^{241}Am citrate were also given ethanol twice daily in their feed and followed for long-term observation. The occurrence of liver tumors in these dogs was compared with that seen in 42 ^{241}Am-injected dogs that did not receive ethanol. A 2- to 3-fold increase in the risk of liver cancer was seen in the ^{241}Am-injected dogs that were also exposed chronically to ethanol. These results indicate that restriction of dietary ethanol may be a prudent part of a treatment regimen in human cases involving hepatic irradiation.

The section on studies originated at the University of Utah is followed by a brief status report on the dogs moved to ITRI from ANL in January 1991; a total of 73 dogs were moved to ITRI. By the end of FY-1991, 18 of these dogs had died or were euthanized. All of the surviving dogs continue to be followed medically, and gross and histopathology information will be obtained at death.

The sections on the ITRI, Utah, and ANL studies are followed by two sections that provide references to open literature and document publications produced by the ITRI and Utah efforts. Specific references to open literature publications during the past fiscal year are included for both organizations.

This annual report concludes with publication of the annually revised appendix tables that list pertinent experimental information for every dog assigned to either an ITRI- or Utah-initiated study. These tables are working documents for which individual entries may change from time to time as new or revised information becomes available. When the information in a specific table reaches the point where further changes are unlikely, it will be so noted. None of the tables has yet reached that stage.

I. ITRI LIFE-SPAN STUDIES IN DOGS

A. SPECIFIC PROJECT OBJECTIVES

The major objectives of these studies are to define the late-occurring health effects of inhaled radionuclides, to determine appropriate dose-response functions for describing the occurrences of these effects, to gain an understanding of the relative importance of various dose- and effect- modifying factors, and to use these results to estimate human health risks from inhaled radionuclides. Because the information necessary to describe these relationships is not available from human exposures to radionuclides, it is necessary to perform studies in laboratory animals to address these issues.

The series of life-span studies conducted in Beagle dogs for this project was designed to determine the toxicity of representative radionuclides from the inventory of various types of nuclear reactors and military production facilities. Specific questions that are addressed in these studies are as follows:

1. What are the organs at risk relative to the solubility of the chemical form of the radionuclides?

2. What is the importance of total dose and dose rate to the lung with respect to beta-emitting radionuclides in producing biological effects?

3. What is the importance of the uniformity of dose to the lung from alpha-emitting radionuclides relative to the risk of lung cancer?

4. Does the age of the individual at the time of exposure modify dose and resulting effects?

5. Does the protraction of dose by repeated exposures have an important effect on biological responses?

Our major focus is on life-span studies in dogs; however, studies are also being done in rodents and in nonhuman primates. The purpose of these latter studies is to provide information from other species that will strengthen and improve the extrapolation of data from laboratory animals to humans.

B. EXPERIMENTAL APPROACHES

1. General Procedures

Each of the dog life-span studies involves dogs that were exposed at one of 4 to 10 levels plus unexposed control dogs. Typically, each exposure level contained 12 dogs, although in a few instances, a particular level contained more or less than 12 dogs. All dogs used were purebred Beagles from the Institute's colony. Before being placed on study, each dog received a complete medical evaluation to ensure its suitability for inclusion in a life-span study. Dogs were placed on study according to a randomized block design. Two or more blocks of dogs, at least one block of each sex, each containing one dog at each desired exposure level and a control dog, were entered on study at a particular time. Entry of the full complement of dogs in a given study was spread over 2 to 5 years.

With the exception of the study in which $^{137}CsCl$ was administered by intravenous injection, all radionuclides were administered by single or repeated, brief, per-nasal inhalation exposure. Dogs were whole-body counted immediately after exposure and periodically thereafter, to quantitate the initial body burden of the inhaled radionuclide and its subsequent retention. Urinary and fecal excretions were collected daily in the early post-exposure period and periodically thereafter, as another means of quantifying radionuclide retention.

All dogs on study received annual medical evaluations, as well as clinical treatment when required. The serial blood cell counts and serum chemistry determinations and the radiographic information were compiled into individual, life-time medical records for each dog. At death, each dog received a complete necropsy, with gross examination of tissues and organs and collections of specimens for histopathology and radioanalysis of radionuclide content. Tissue specimens were examined histopathologically, and a case summary and diagnoses were prepared. Additional dosimetry data were obtained from the serial sacrifice of dogs exposed in parallel studies using the same radionuclides and aerosol forms as in the life-span studies. Histopathology results are encoded according to the SNODOG, a modified version of the SNOMED nomenclature system, and entered into a FOCUS data base along with major clinical results for each dog.

2. Study-Specific Features

a. Beta-Emitting Radionuclides Inhaled in a Relatively Soluble Form

The solubility of inhaled material in body fluids has a definite effect on the translocation of radionuclides from the lung and influences which organs receive significant radiation doses. The four radionuclide compounds chosen for these studies, $^{90}SrCl_2$, $^{144}CeCl_3$, $^{91}YCl_3$ and $^{137}CsCl$, provided a range of organs at risk, including lung, liver, skeleton and whole body. For the purposes of this report, use of the terms ^{90}Sr, ^{137}Cs or ^{144}Ce refers to an equilibrium mixture of ^{90}Sr-^{90}Y, ^{137}Cs-^{137m}Ba, or ^{144}Ce-^{144}Pr, respectively. Specific features of these four studies are given below.

i. $^{90}SrCl_2$ (Inhalation exposures performed from 1965-1967)

This study involves 48 dogs that received single inhalation exposures to graded levels of ^{90}Sr and 15 control dogs. The exposure aerosol was $^{90}SrCl_2$ in a nonradioactive CsCl vector. The long-term retained burdens ranged from 0.37 to 4.44 MBq/kg body weight. Because ^{90}Sr is a bone-seeking radionuclide, the skeleton was the main target organ.

ii. $^{144}CeCl_3$ (Inhalation exposures performed from 1966-1967)

This study involves 55 dogs that received single inhalation exposures to $^{144}CeCl_3$ on a CsCl vector and 17 control dogs. The long-term retained burdens ranged from 0.090 to 13.3 MBq/kg body weight. The main target organs were lung, liver, skeleton and nasal cavity.

iii. $^{91}YCl_3$ (Inhalation exposures performed from 1966-1967)

This study involves 42 dogs that received single inhalation exposures to $^{91}YCl_3$ on a CsCl vector and 12 control dogs. The long-term retained burdens ranged from 0.52 to 20 MBq/kg body weight. The main target organs were similar to those for ^{144}Ce - lung, liver, skeleton and nasal cavity.

iv. $^{137}CsCl$ (Intravenous injections were done in 1968-1969)

This study involves 54 dogs that received a single intravenous injection of $^{137}CsCl$ and 12 control dogs. The initial body burdens of ^{137}Cs in the injected dogs ranged from 32.5 to 148 MBq/kg body weight. Because of the soluble nature of the injected material and the fact that the distribution of sium follows that of potassium in the body, the resulting pattern of irradiation was generally a whole-body exposure, in contrast to the three studies listed above where the radionuclides were preferentially deposited in only a few organs.

b. Beta-Emitting Radionuclides Inhaled in a Relatively Insoluble Form

This series of four studies was designed to investigate the carcinogenic response of the lung to similar doses of chronic beta radiation delivered over different periods of time. To achieve this objective, four radionuclides, with radioactive half-lives ranging from 64 hours to 29 years and each encapsulated in a common form of vector aerosol, fused aluminosilicate particles (FAP), were studied. Specific features of these four studies are given below.

i. ^{90}Y in fused aluminosilicate particles (Inhalation exposures performed from 1969-1971)

This study involves 89 dogs that received single inhalation exposures to ^{90}Y-FAP and 12 control dogs. The initial lung burdens (ILB) ranged from 2.96 to 192 MBq/kg body weight. Because the half-life of ^{90}Y is relatively short, 2.6 days, and ^{90}Y in this form is relatively insoluble, the major radiation dose was delivered to the lung.

ii. ^{91}Y in fused aluminosilicate particles (Inhalation exposures performed from 1970-1971)

This study involves 96 dogs exposed once to graded levels of ^{91}Y-FAP and 12 control dogs. ILB ranged from 0.407 to 13.3 MBq/kg body weight. The effective half-life of ^{91}Y is approximately 53 days in the lung. The main target organs were the lung and tracheobronchial lymph nodes.

iii. ^{144}Ce in fused aluminosilicate particles (Inhalation exposures performed from 1967-1971)

This study involves 111 dogs that received single brief exposures to ^{144}Ce-FAP as young adults and 15 control dogs. ILB ranged from 0.00009 to 7.77 MBq/kg. The effective half-life of ^{144}Ce in the lung is about 180 days. Lung and tracheobronchial lymph nodes were the main target organs.

iv. ^{90}Sr in fused aluminosilicate particles (Inhalation exposures performed from 1970-1974)

This study involves 106 dogs that received single brief exposures to ^{90}Sr-FAP as young adults and 18 control dogs. ILB ranged from 0.0044 to 3.55 MBq/kg body weight. The radioactive half-life of ^{90}Sr, about 29 years, is the longest of the four radionuclides used in this series. When incorporated in FAP, the effective pulmonary retention half-life is about 500 days. The main target organs were lung and tracheobronchial lymph nodes.

Figures 1 and 2 illustrate the effect of different retention patterns in the lung for the four studies in which young adult dogs inhaled radionuclides in FAP aerosols. These differences result from effective half-lives in lung that range from ~ 2 days for ^{90}Y to more than 500 days for ^{90}Sr. In Figure 1, the expected change in radiation dose rate as a function of time is shown for the levels of exposure selected to produce initial dose rates of 1 Gy/day. The dose patterns in Figure 1 required assignment of similar activity levels for ILB, because the beta energies

are similar for the four radionuclides. For the same ILB, different dose-rate patterns result in marked differences in the long-term cumulative radiation dose to the lung. Differences in radiation dose patterns among the different radionuclides are demonstrated in Figure 2, where cumulative dose curves resulting in infinite doses of 20 Gy to the lung required ILB ranging from 48 MBq for ^{90}Y (initial dose rate = 5.3 Gy/day) to 0.26 MBq for ^{90}Sr (initial dose rate = 0.57 Gy/day). Table 1 shows the various organs that received substantial beta radiation doses in these studies and thus, were especially at risk for the development of long-term biological effects.

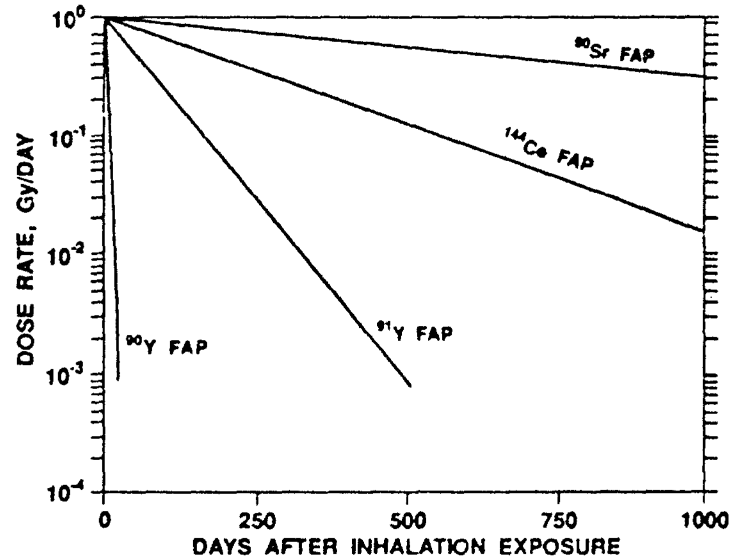

Figure 1. Calculated absorbed beta dose rate to the lung for Beagle dogs for various inhaled radionuclides normalized to 1 Gy/day initial dose rate (110 g lung). FAP = fused aluminosilicate particles.

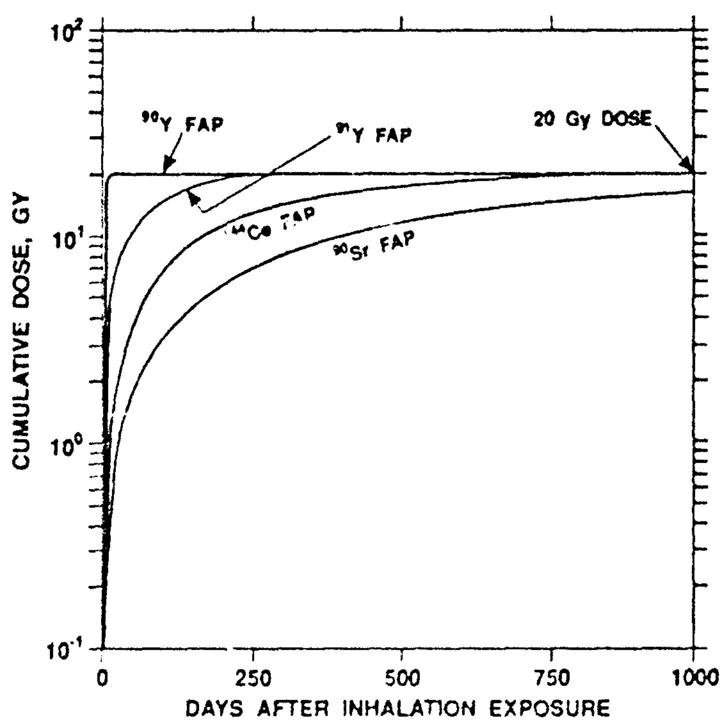

Figure 2. Calculated patterns for accumulating total beta-dose to the lung in Beagle dogs of 20 Gy from various inhaled radionuclides (110 g lung). FAP = fused aluminosilicate particles.

Table 1

Life-Span Dose-Response Studies in Beagle Dogs that Received Single, Brief Exposures by Inhalation To Beta-Emitting Radionuclides

Aerosol and Form[a]	Whole-Body Effective Retention Half-Life	Age at Inhalation Exposure	Organs Receiving Substantial Radiation Doses				
			Lung	Skeleton	Liver	Whole Body	TBLN[b]
$^{137}CsCl$	30 days	13 months				+ +[c]	
$^{91}YCl_3$	59 days	13 months	+ +	+ +	+ +		
$^{144}CeCl_3$	284 days	13 months	+ +	+ +	+ + +		
$^{90}SrCl_2$	5-10 years	13 months		+ + +			
^{90}Y FAP[d]	2.5 days	13 months	+ +				+
^{91}Y FAP	53 days	13 months	+ + +				+ +
^{144}Ce FAP	≃ 200 days	13 months	+ + +	+	+		+ + +
^{90}Sr FAP	> 500 days	13 months	+ + +	+	+		+ + +
^{144}Ce FAP	≃ 200 days	3 months	+ + +	+	+		+ + +
^{144}Ce FAP	≃ 200 days	8-10 years	+ + +	+	+		+ + +

[a]All polydisperse aerosols, except $^{137}CsCl$ which was given by intravenous injection.
[b]Tracheobronchial lymph nodes.
[c]Relative magnitude of dose received.
[d]Fused aluminosilicate particles.

c. Uniformity of Pulmonary Irradiation from an Inhaled Alpha-Emitting Radionuclide

To address the question of whether a nonuniform distribution of alpha radiation in the lung is more carcinogenic than a uniform distribution, five life-span studies are being conducted using Beagle dogs that inhaled either $^{238}PuO_2$ or $^{239}PuO_2$ particles of different monodisperse sizes. A schematic representation of the experimental design for these studies is shown in Figure 3, where each cube represents one dog. Five different aerosols have been used, each resulting in particles with different levels of alpha-emitter radioactivity. For each aerosol, a randomized block design was used for entering dogs on study, similar to that used for the beta-gamma dose-response studies.

Twelve blocks of dogs were exposed to each aerosol to achieve graded ILB ranging from 0.37-21 kBq Pu/kg body weight. Sixty control dogs were included, 12 for each aerosol. Two additional ILB levels of 93 and 8.5 Bq Pu/kg body weight were included for the studies in which young-adult dogs and immature dogs inhaled $^{239}PuO_2$ aerosols of 1.5-μm activity median aerodynamic diameter (AMAD). An ILB of ^{239}Pu of 8.5 Bq Pu/kg body weight in a Beagle dog is equivalent to a lung burden of 590 kBq Pu in a 70-kg human.

The information given in Table 2 and in Figure 3 was used to calculate the initial dose rate averaged over the total lung and the local dose rate around each particle, for each particle size and activity level shown in Figure 4. With two different radioisotopes of plutonium and three different particle sizes, the alpha activity per particle and the corresponding, idealized local dose rate to a sphere of lung tissue with a radius of 180 μm (density = 0.22 g/cm^3) surrounding an individual particle varied by a factor of ˜ 40,000. Also, the use of six activity levels for each aerosol resulted in a difference of about a factor of 50 in the initial dose rate, averaged over the entire lung. Thus, these five experiments permit comparison of the relative influences of both local dose

rates and average dose rates in producing long-term biological effects. The average dose rate to the lung will decrease with time after exposure, as plutonium is cleared from the lung. The local dose rate can either increase or decrease as a result of particle movement, aggregation, dissolution, or particle breakup in the lung.

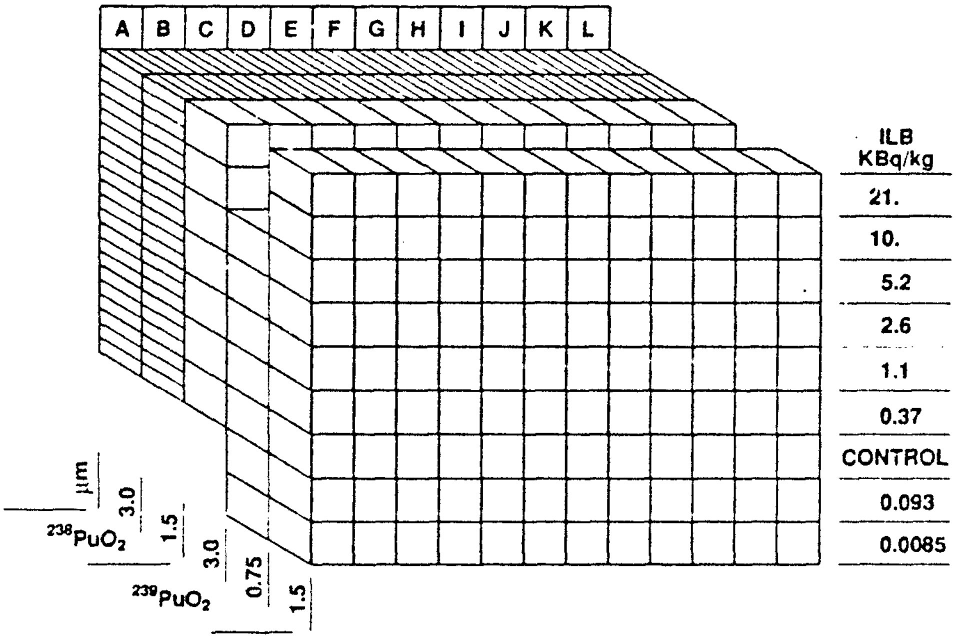

Figure 3. Schematic representation of the experimental design for life-span studies involving young adult dogs exposed to different monodisperse aerosols of ^{238}Pu (90%)PuO_2 or $^{239}PuO_2$. Each cube represents one dog entered into the experiment at 12-14 months of age.

Table 2

Some Characteristics of Aerosol Particles Containing Pure Transuranic Alpha-Emitting Radionuclides

Aerosol	Specific Activity (GBq/g)	Activity (Bq) per Particle[a,b] AMAD[c] = 0.75 µm RD[d] = 0.18 µm	AMAD = 1.5 µm RD = 0.44 µm	AMAD = 3.0 µm RD = 0.96 µm
$^{239}PuO_2$	2.0	0.000049	0.00074	0.0074
$^{241}AmO_2$	110	0.0027	0.039	0.41
$^{238}PuO_2$	560	0.014	0.20	2.1
$^{244}CmO_x$	2,700	0.066	0.96	10
$^{242}CmO_x$	110,000	2.7	39	410

[a]Density of 8 was used for these calculations. This is the measured density for $^{238}PuO_2$ and $^{241}AmO_2$ particles produced by standard methods at this Institute.
[b]The ^{238}Pu used at this Institute contained 10% ^{239}Pu by weight. This produced a specific activity of 510 GBq/g and particle activities of 0.013, 0.18 and 1.9 Bq, respectively, for 0.75-µm, 1.5-µm, and 3.0-µm AMAD particles.
[c]AMAD = Activity median aerodynamic diameter of monodisperse particles (geometric standard deviation < 1.2).
[d]RD = Real or geometric diameter of the particle.

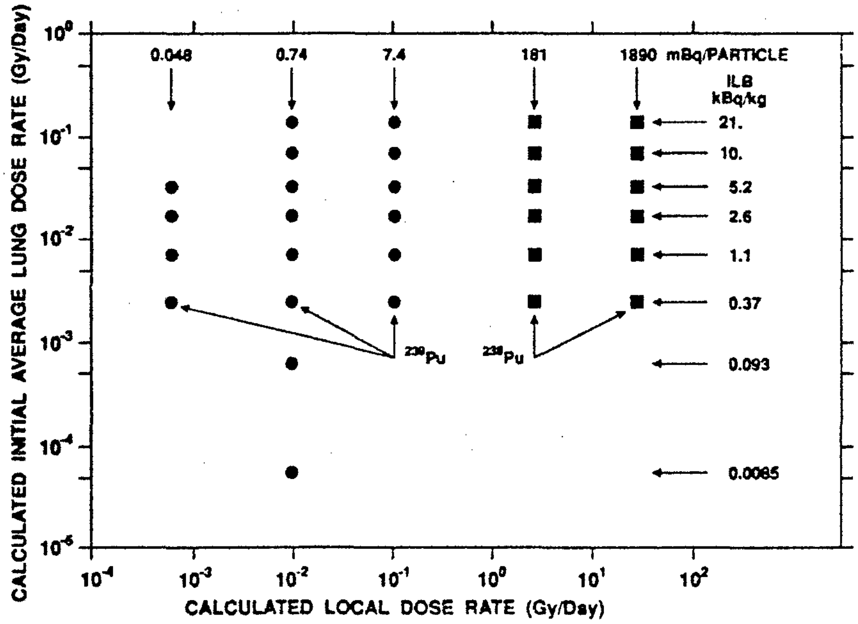

Figure 4. Calculated dose relationships for the five life-span studies involving dogs that inhaled monodisperse aerosols of $^{238}(90\%)PuO_2$ or $^{239}PuO_2$. Local dose rate was computed in a 180-μm sphere of lung tissue (density = 0.22 g/cm^3). The calculation of average dose rate was based on a 110-g lung. Self-absorption of alpha energy by the particles was negligible.

Inherent in the experimental design is a difference in the number of particles associated with a given ILB level for each aerosol. The fraction of the lung irradiated can be estimated by assuming a spherical irradiation volume of 2.4×10^7 μm^3 around each particle, and by determining how many of these volumes are present in the volume of a 110-g lung. Results of such a theoretical calculation are presented in Figure 5. When the number of these irradiation volumes exceeds 2.1×10^7, the calculated fraction of lung irradiated exceeds 1.0. For values > 1.0, some or all portions of the lung would be irradiated by the alpha emissions from more than one particle of plutonium, even if the particles are assumed to be uniformly distributed in the lung tissue, and geometrical considerations are ignored. Our experimental evidence suggests that inhaled particles are not uniformly distributed, but are randomly deposited in the lung. This random distribution indicates that theoretical calculations of the fraction of lung irradiated are slight overestimates. All of the ILB levels for the exposures to 0.75-μm AMAD particles of $^{239}PuO_2$ and for the upper four levels for the exposures to 1.5-μm AMAD particles of $^{239}PuO_2$ gave calculated fractional irradiations > 1.0. The remaining $^{239}PuO_2$ ILB levels and all of the $^{238}PuO_2$ exposure levels resulted in calculated values < 1.0 for fractions of lung irradiated. Because of the overlap in fractions of lung irradiated for the several different sizes of aerosols, the effects of local dose rate are being studied, while the fraction of lung irradiated is held constant. To obtain more detailed dosimetric information, parallel studies have been conducted in dogs and rodents exposed to $^{239}PuO_2$ and $^{238}PuO_2$ aerosols and serially sacrificed at selected times after exposure. These studies have provided valuable data on the organ and tissue distribution of plutonium with time after exposure.

The dogs in the originally planned five studies of different-sized aerosol particles of $^{239}PuO_2$ and $^{238}PuO_2$ have all been exposed and entered into these studies. After the exposures were completed, we found that the $^{238}PuO_2$ particles began to break up in the lung at about 100 days after exposure. This resulted in increased solubility and translocation of ^{238}Pu to bone and liver. Although some $^{238}PuO_2$ remained in the lung, the dose patterns to lung, liver and bone were altered from what was initially expected to occur. The $^{239}PuO_2$ particles did not undergo any observable breakup, presumably because of their lower specific activity. Although this unexpected early dissolution of the $^{238}PuO_2$ particles changed the experimental design of the original study, important information is being obtained on the toxicity of inhaled $^{238}PuO_2$. At the same time, the $^{239}PuO_2$-exposed dogs are providing information relative to the original hypothesis.

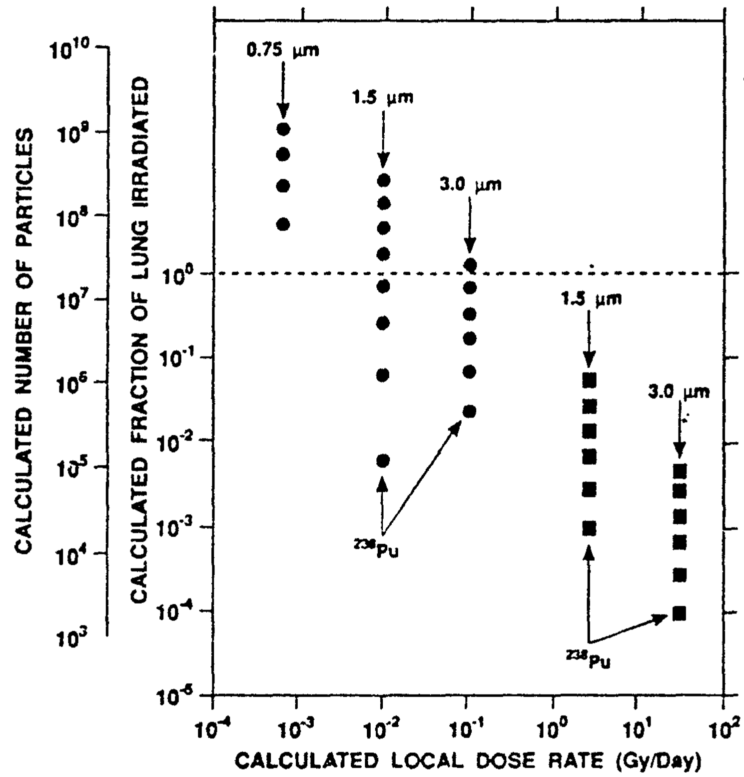

Figure 5. Calculated numbers of particles and fractions of lung irradiated based on the sphere of irradiation associated with each particle ($2.4 \times 10^7\ \mu m^3$) and a determination of how many of these volumes could be contained in the lung before overlapping occurred. Self-absorption of alpha energy by the particles is negligible.

Specific details on these studies are given below.

i. $^{238}PuO_2$ (Inhalation exposures performed from 1973-1976)

Two studies were initiated with young-adult dogs exposed once, briefly, to monodisperse particles of $^{238}PuO_2$. These two studies used particles with aerodynamic diameters of 1.5 and 3.0 μm, respectively. Each study was comprised of 72 ^{238}Pu-exposed dogs and 12 control dogs. The ILB ranged from 0.11 to 37 kBq/kg body weight in the 1.5 μm study and 0.37 to 55.5 kBq/kg body weight in the 3.0 μm study. Although the particles of $^{238}PuO_2$ were initially quite insoluble, these particles fractured after several months in the body, leading to decreased particle sizes and increased dissolution. Subsequent absorption of ^{238}Pu into the systemic circulation, with translocation to other organs, resulted in the skeleton and liver becoming target organs, as well as the lung.

ii. $^{239}PuO_2$ (Inhalation exposures performed from 1977-1979)

Three studies were initiated in which young-adult dogs were exposed once, briefly, to monodisperse particles. There were 48 dogs that inhaled 0.75 μm particles of $^{239}PuO_2$, 96 dogs that inhaled 1.5 μm particles of $^{239}PuO_2$ and 72 dogs that inhaled 3.0 μm particles of $^{239}PuO_2$. Each study had 12 control dogs. The ILB ranged from 0.26 to 7.4, from 0.03 to 37, and from 0.22 to 74 kBq/kg body weight for the 0.75 μm, 1.0 μm, and 3.0 μm studies, respectively. Because the inhaled $^{239}PuO_2$ remained in a very insoluble form in the body, the lungs were the main target organs in these studies.

d. Effects of Age

To examine the possible effects of age on the dose-response relationships for both a beta- and an alpha-emitting radionuclide inhaled in a relatively insoluble form, additional life-span studies were conducted with dogs that were either 3 months or 8 to 10.5 years old at the time of inhalation exposure. The two exposure aerosols used, ^{144}Ce-FAP and $^{239}PuO_2$, will facilitate comparisons of results obtained with beta- and alpha-emitting radionuclides with results obtained from the companion, young-adult studies listed above for the same forms.

i. ^{144}Ce in fused aluminosilicate particles in immature dogs (Inhalation exposures performed from 1972-1976)

This study involved 49 dogs that were exposed once, briefly, to ^{144}Ce-FAP aerosols at 90 days of age and five control dogs. The ILB of ^{144}Ce ranged from 0.15 to 5,180 kBq/kg body weight. The lung and tracheobronchial lymph nodes were the main target organs.

ii. ^{144}Ce in fused aluminosilicate particles in aged dogs (Inhalation exposures performed from 1972-1975)

This study involves 42 dogs that inhaled graded activity levels of ^{144}Ce-FAP when they were 8 to 10.5 years old and 12 control dogs. ILBs in these 42 dogs ranged from 88.8 to 2,780 kBq/kg body weight. The main target organs were lung and tracheobronchial lymph nodes.

iii. $^{239}PuO_2$ in immature dogs (Inhalation exposures performed from 1979-1982)

This study involves 96 dogs that inhaled graded activity levels of a 1.5 μm monodisperse aerosol of $^{239}PuO_2$ when they were 90 days old and 12 control dogs. The ILB ranged from 0.01 to 29 kBq/kg body weight. Lung and tracheobronchial lymph nodes were the primary target organs.

iv. $^{239}PuO_2$ in aged dogs (Inhalation exposures performed from 1979-1982)

This study involves 48 dogs that inhaled 1.5 μm particles of $^{239}PuO_2$ when they were 8 to 10.5 years old and 12 control dogs. The ILB ranged from 0.48 to 24 kBq/kg body weight. Lung and tracheobronchial lymph nodes were the main target organs.

e. Effects of Protracted Exposure

Two studies were conducted to study dose protraction, one with a beta emitter, ^{144}Ce, and one with an alpha emitter, ^{239}Pu.

i. ^{144}Ce in fused aluminosilicate particles repeated exposures (Inhalation exposures performed from 1973-1975)

This study involves 27 dogs that received a brief inhalation exposure to ^{144}Ce-FAP every 8 weeks for 13 exposures, and nine control dogs. The 27 exposed dogs were divided into three groups of nine dogs, whose lung burdens of ^{144}Ce were 1) increased by 92 kBq/kg with each exposure, 2) re-established at 333 kBq/kg, or 3) re-established at 165 kBq/kg body weight. In each case, lung and tracheobronchial lymph nodes were the main target organs.

ii. $^{239}PuO_2$ repeated exposures (Inhalation exposures performed from 1977-1988)

This study involves 36 dogs that received a brief inhalation exposure to $^{239}PuO_2$ every 6 months for 20 exposures. These 36 dogs were divided into two groups, for which the exposure goals and numbers of dogs were 1) lung burden increased 3.7 kBq every 6 months (12 dogs) and 2) lung burden increased 0.37 kBq every

6 months (24 dogs). Another group of 24 dogs received an ILB of about 3.7 kBq in one brief inhalation exposure. Twelve dogs served as controls. The singly exposed dogs and the controls were sham exposed 19 times. Lung and tracheobronchial lymph nodes were the target organs.

3. Additional Approaches Being Used in the Life-Span Studies

Additional approaches to acquiring biological information related to the pathogenesis of alpha radiation-induced lung disease have been implemented in animals in the ongoing studies. Because about 61% of the dogs exposed as immature animals are still alive, these dogs are currently our most available population for studying the mechanisms of radiation-induced lung cancer. Biologic materials from animals in this project are being used in other projects, "Molecular Bases of Radiation-Induced Cancers" and "Mechanism of Radiation-Induced Cancer" to achieve two goals: 1) to develop early biological indicators of lung tumor production, and 2) to elucidate the mechanisms involved in alpha radiation carcinogenesis. Immunohistochemical and molecular techniques are being used to determine the presence and extent of dysfunctional expressions within hyperplastic epithelial foci, lung tumors, and exfoliated cells. For example, tissue samples are being used to measure oncogene amplification and tumor-associated restriction fragment-length polymorphisms by Southern blot techniques. Mutations that activate the Kirsten-*ras* proto-oncogene are being assayed by oligonucleotide mismatch hybridization and DNA sequence analysis following amplification of the first and second exons of the Ki-*ras* gene using the polymerase chain reaction. Immunohistochemistry is being used to assay for p53 tumor suppressor gene and Erb B-2 oncogene dysfunctions and fluorescent *in situ* hybridization to score for chromosomal gains and losses. The resulting data will provide clues to the sequence of gene dysfunction that lead to neoplastic transformation. Although these kinds of biochemical and whole-tissue studies are being done in other projects, the information obtained will form an integral part of the results from the studies in this project.

C. CURRENT STATUS OF ITRI STUDIES

1. General Overview

The current status of the 19 dog longevity studies at ITRI is presented in Table 3. Overall, about 7 percent of the total population of study dogs remained alive on September 30, 1991. Thirteen of these studies have reached the point at which all of the dogs are now dead, and several others will soon reach this same point. At the current time, our research effort related to these studies has three main foci: 1) continuation of the care and study of dogs still alive in six of these studies, 2) use of biological specimens obtained at necropsy to develop early biological indicators of lung tumor production and to study the underlying mechanisms and 3) completion of final reviews of biological specimens and the associated dosimetry data, compilation and analysis of data, and preparation of final study reports for publication in the open scientific literature. When a study is fully completed and submitted for publication, the study materials (slides, tissue blocks, etc.) records, and computer files will be transferred to the National Radiobiology Archive at Richland, WA.

The brief reports that follow in Section I.C.2. give the current status of each longevity study in which dogs remain alive. This section is followed by a compilation of pertinent references to previous animal reports for all 11 studies in which all dogs are now dead (Section I.C.3.). These status reports are followed by a series of progress reports that present current highlights related to the three main research areas.

Table 3

Current Status of Life-Span Radionuclide Toxicology Studies in Beagle Dogs at the Inhalation Toxicology Research Institute (9/30/91)

Age at Inhalation	Radionuclide and Form	Inhalation Exposure Year	Dogs Entered in Study	Number Alive 9/30/90	FY-1990 Deaths	Number Alive 9/30/91
12-14 mo. (young adult)	$^{90}SrCl_2$	1965-1967	63	0	0	0
	$^{144}CeCl_3$	1966-1967	72	0	0	0
	$^{91}YCl_3$	1966-1967	44	0	0	0
	$^{137}CsCl$	1968-1969	66	0	0	0
	^{90}Y-FAP	1969-1971	101	0	0	0
	^{91}Y-FAP	1970-1971	108	0	0	0
	^{144}Ce-FAP	1967-1971	126	0	0	0
	^{90}Sr-FAP	1970-1974	124	1	1	0
	$^{238}PuO_2$ (1.5)	1974-1976	84	1	1	0
	$^{238}PuO_2$ (3.0)	1973-1976	84	0	0	0
	$^{239}PuO_2$ (0.75)	1977-1979	60	5	1	4
	$^{239}PuO_2$ (1.5)	1977-1979	108	26	5	21
	$^{239}PuO_2$ (3.0)	1977-1979	84	11	3	8
3 mo. (immature)	^{144}Ce-FAP	1972-1976	54	2	1	1
	$^{239}PuO_2$	1979-1982	108	72	6	66
8-10.5 yr. (aged)	^{144}Ce-FAP	1972-1975	54	0	0	0
	$^{239}PuO_2$	1979-1982	60	0	0	0
Began at 12-14 mo.	^{144}Ce-FAP Repeated	1973-1975	36	0	0	0
	$^{239}PuO_2$ Repeated	1977-1988	72	13	7	6
		Total	1508	157	26	131

2. Summary Reports for Studies with Living Dogs

a. Toxicity of ^{90}Sr Inhaled in a Relatively Insoluble Form By Beagle Dogs. XIX.

Study Contact: M. B. Snipes

To determine the health effects resulting from inhalation of ^{90}Sr in a relatively insoluble form, Beagle dogs were briefly exposed by inhalation to ^{90}Sr in fused aluminosilicate particles and maintained for life-span observations. One hundred and six dogs had ILB of ^{90}Sr ranging from 0.0044-3.5 MBq/kg body weight (0.12-96 μCi/kg). Eighteen control dogs inhaled fused aluminosilicate particles. The initial 12 blocks of dogs were exposed in 1970 and 1971. The last six blocks of dogs were exposed to lower concentrations of ^{90}Sr in 1974, when it was recognized that many of the dogs initially exposed died of radiation pneumonitis or hemangiosarcomas of the lung within 3 years after inhalation exposure. Specific details on the experimental design of the study, and the metabolism, dosimetry, and biologic effects of inhaled ^{90}Sr are presented in previous annual reports from the Institute, particularly in LF-44 (1970-71), LF-52 (1974-75) and LF-91 (1980-81).

Annual summaries for this study, including a synopsis of pathology findings for each dog that died, have been included in each annual report since LF-44 (1970-71). The current status of this study is shown in the experimental design chart given in Figure 6. Exposure information, dosimetry results, and major findings at death, are given for each dog in Appendix A. Survival data are summarized in Figure 7. A summary of the major findings at death is given in Table 4.

During the past year, the last living dog in this study died. Dog 762T, a female control, was found dead 6025 days after inhalation exposure to the vector aerosol. This dog had several minor clinical problems during its lifetime. Included were three complex mammary adenocarcinomas, a simple solid mammary carcinoma, three complex mammary adenomas, a benign mixed mammary tumor, and an oral malignant melanoma of the spindle cell type. An ovariohysterectomy was performed about 2 years prior to death. Uterine lesions consisted of moderate, cystic, endometrial hyperplasia and focal adenomyosis. Ovarian lesions consisted of bilateral parovarian cysts and a unilateral (left) benign granulosa cell tumor. Right heart enlargement was noted 6 months prior to death. Hematuria was noted about 5 months prior to death.

At necropsy, dehydration, mineralization of coronary and splenic arterioles, osteopenia, chronic pyelonephritis, and chronic papillary necrosis were all consistent with a primary cause of death of renal failure associated with chronic, moderate, pyelonephritis with mild nephrocalcinosis. Chronic passive congestion in the liver suggested right heart failure but ascites and clinical liver failure were not present nor were there gross or microscopic lesions in the right side of the heart. Moderate arteriosclerosis (amyloidosis) of arterioles was noted in the pulmonary vasculature, and it is speculated that right heart enlargement and decreased function was secondary to pulmonary hypertension. A focal scar, most likely a healed infarct, was noted grossly in the left ventricular myocardium and potentially related to focal intimal hyperplasia in an extramural coronary artery and multifocal mineralization of coronary arterioles. A solitary papillary pulmonary adenocarcinoma of the right apical lung lobe was an incidental finding.

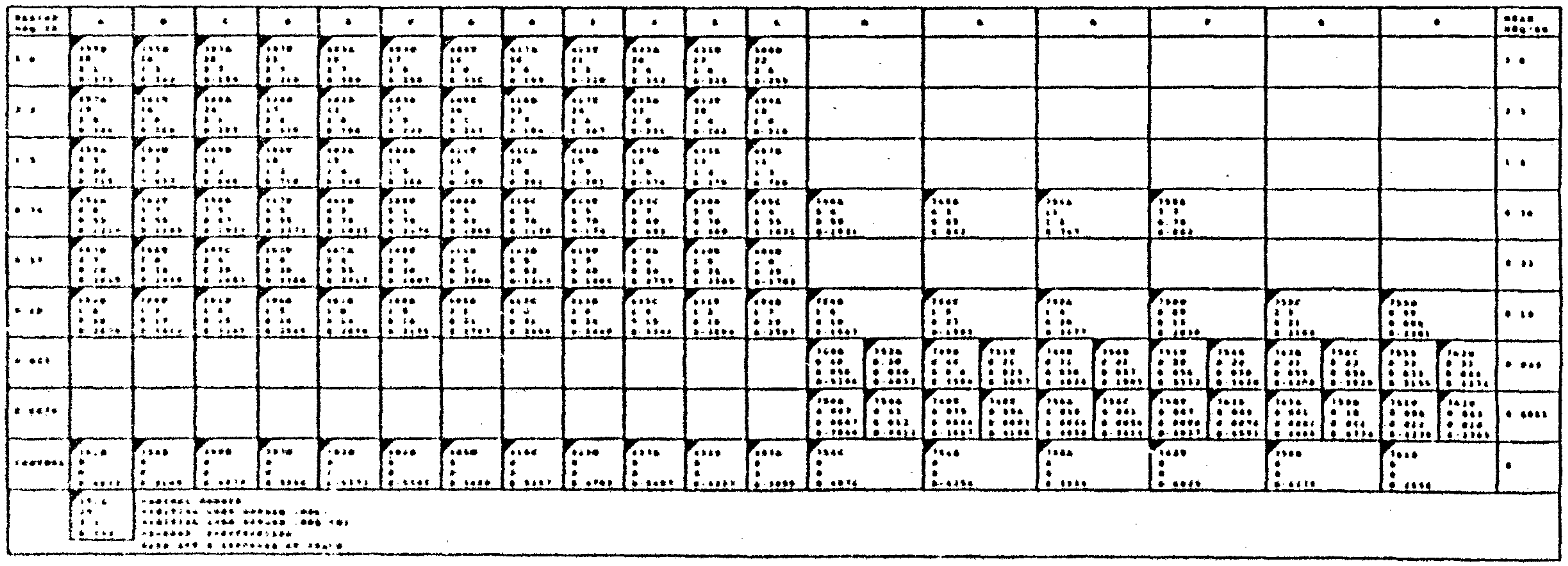

Figure 6. Experimental design for life span study of Beagle dogs exposed by inhalation to ^{90}Sr in a fused aluminosilicate matrix (Status as of 9-30-91).

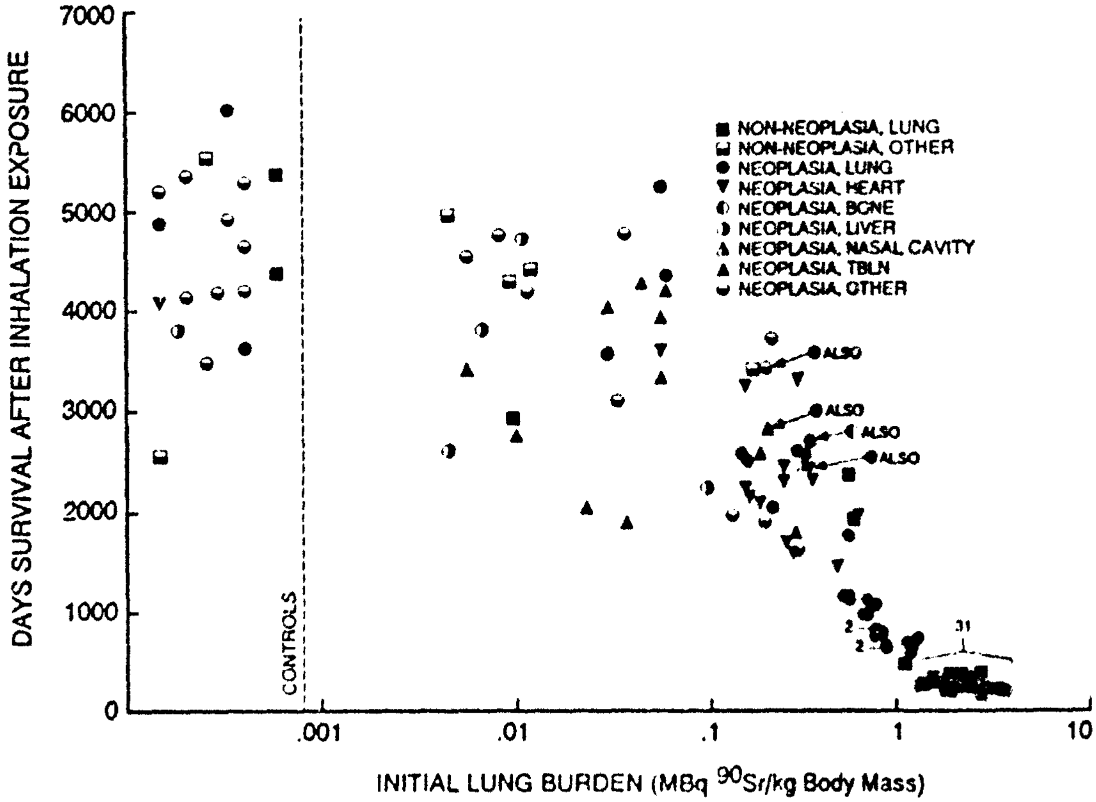

Figure 7. Relationship between ILB of ^{90}Sr and survival time for Beagle dogs that inhaled ^{90}Sr in a fused aluminosilicate matrix (Status as of 9-30-91).

Table 4

Summary of Major Findings at Death in Dogs Exposed by Inhalation to ^{90}Sr in Fused Aluminosilicate Particles (Status as of 9-30-91)

	Number of Dogs	ILB[a] (MBq ^{90}Sr/kg Body Weight)	Survival Times (Days after Exposure)	Cumulative Radiation Dose to Lung (Gy)
^{90}Sr-Exposed				
Non-Neoplasia				
Lung	35	.0096-3.6	159-2925	10-990
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	4	.0044-.17	3412-4958	6.2-140
Neoplasia				
Lung Injury with Lung Neoplasia	0	--		--
Lung	30[b,c,d,e]	.030-1.3	644-5296	44-720
Nasal Epithelium	1	.31	2496	310
TBLN	12[c]	.0056-.28	1807-4274	7.7-310
Heart	14[e]	.056-.63	1461-3594	85-580
Bone	1[d]	.34	2753	360
Bone Marrow	0	--	--	--
Liver	4	.0044-.10	2301-4774	5.5-110
Other	10[b]	.0056-.29	1683-4824	5.7-310
Control				
Non-Neoplasia				
Lung	2	--	4375,5372	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	3[f]	--	2558-6025	--
Neoplasia		--	--	--
Lung Injury with Lung Neoplasia	0	--	--	--
Lung	3[f]	--	3680-6025	--
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	1	--	4076	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	1	--	3859	--
Other	9	--	3534-5407	--

[a]ILB = Initial Lung Burden

[b]One dog had an hemangiosarcoma, site undermined, and a pulmonary adenoma.

[c]Two dogs had TLBN and lung tumors.

[d]One dog had bone and lung tumors.

[e]One dog had heart and lung tumors.

[f]One dog had lung carcinoma and pyelonephritis.

b. Toxicity of Inhaled $^{238}PuO_2$ in Beagle Dogs. XVII:

i. Monodisperse 1.5 μm AMAD Particles.

ii. Monodisperse 3.0 μm AMAD Particles.

Study Contact: B. A. Muggenburg

This study is part of a larger investigation of the potential effect of different alpha-radiation dose distributions in the lung and other organs upon the biological effects produced in Beagle dogs. Young-adult dogs of both sexes inhaled one of two sizes of monodisperse aerosols of $^{238}PuO_2$ resulting in graded levels of ^{238}Pu in the lung. All of the dogs have been studied for their life spans. Seventy-two dogs inhaled monodisperse, 1.5 μm AMAD aerosols of $^{238}PuO_2$, and 72 dogs inhaled monodisperse 3.0 μm AMAD aerosols. The ILB of ^{238}Pu ranged from 37 to 0.11 kBq/kg body mass (1.5 μm) and 55.5 to 0.37 kBq/kg body mass (3.0 μm). In addition, 24 dogs inhaled the aerosol vector only and served as controls, 12 for each particle size. The exposures took place from 1974 to 1976. Specific details on the experimental design of the study, medical evaluation of the dogs, and the metabolism and dosimetry of ^{238}Pu are presented in previous annual reports, especially the 1972-1973 Annual Report, LF-46, pp. 1-9 and 78-80; 1973-1974 Annual Report, LF-49, pp. 140-144; 1976-1977 Annual Report, LF-58, pp. 122-134; and 1978-1979 Annual Report, LF-69, pp. 9-13 and 122-133. The biological effects have been presented as descriptions of the clinical-pathology findings for each dog in the annual report for the year in which the dog died. Annual summaries for this study have also been included in all annual reports, from 1974 to the present.

Experimental designs for this study are shown schematically in Figures 8 and 9. Exposure information, dosimetry results, and major diseases at death are given for each dog in Appendix A. Survival data for dogs in this study are summarized graphically in Figures 10 and 11.

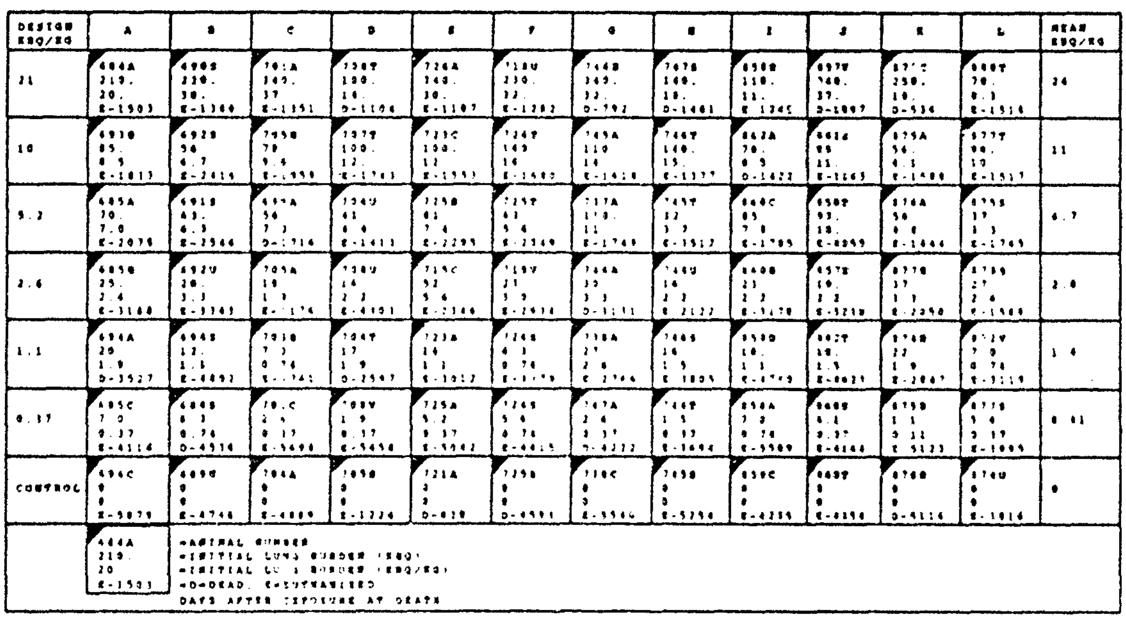

Figure 8. Experimental design for dose-response study of Beagle dogs exposed by inhalation to 1.5 μm AMAD aerosols of $^{238}PuO_2$ (Status as of 9-30-91).

DESIGN KBQ/KG	A	B	C	D	E	F	G	H	I	J	K	L	MEAN KBQ/KG
21	674B 270. 30. D-1683	667T 400. 56. D-1213	696A 300. 27. E-1528	703S 140. 20. E-1568	710C 420. 48. E-631	711S 160. 21. E-1543	736A 340. 34. E-1181	731S 140. 22. E-1161	852B 150. 15. E-1707	849S 200. 24. E-1184	866A 350. 30. E-1319	865S 100. 14. E-1672	28
10	674A 160. 14. E-1556	667S 340. 34. E-1432	695A 170. 14. D-1918	696S 89. 16. E-1610	708A 130. 12. E-1409	716T 110. 15. E-1416	733A 67. 6.7 E-1202	736S 150. 19. D-966	846A 130. 11. E-1372	848S 56. 5.9 E-3491	867A 140. 11. E-1588	870V 93. 7.8 E-1729	14
5.2	680S 140. 14. D-2143	682V 130. 15. E-1550	697B 160. 13. E-1125	702S 22. 2.6 E-3612	715B 81. 8.5 E-1699	714U 25. 4.1 E-3532	736E 70. 4.3 E-1640	730S 65. 7.8 D-1977	844B 63. 6.3 E-1778	848T 27. 3.3 E-3393	865D 32. 3.3 E-2624	869T 37. 4.8 E-1573	7.4
2.6	674C 37. 3.3 E-3741	678T 52. 6.3 D-2737	696D 34. 4.8 E-2958	697S 11. 1.5 E-3222	715A 56. 6.3 E-2174	711T 18. 2.6 D-4042	732A 23. 2.8 E-2415	733S 25. 2.6 E-4054	854B 19. 2.6 E-3831	856T 15. 2.6 E-3804	874A 37. 2.6 E-2835	849U 19. 2.2 D-1932	3.3
1.1	680A 41. 3.3 E-2385	680T 11. 1.9 E-4123	697A 20. 1.9 E-4386	704S 13. 1.5 E-3566	705C 15. 1.6 D-3046	715S 9.6 1.5 E-4815	735C 21. 2.2 E-4234	734S 9.6 1.1 E-3831	846C 27. 2.6 D-3620	857S 15. 1.1 D-1525	865B 8.1 0.74 E-4577	872S 17. 1.5 E-3437	1.7
0.37	679B 6.7 0.71 E-4345	680S 4.8 0.74 E-4959	697D 3.0 0.37 D-4853	699S 5.2 0.74 D-4848	708C 1.5 0.37 E-5788	716S 9.3 1.1 E-3879	732B 7.8 0.78 D-1954	734T 4.8 0.37 E-4480	849C 8.3 0.74 E-3043	856S 5.6 0.74 E-4749	871B 9.6 0.74 E-4725	878T 4.1 0.37 D-2454	0.59
CONTROL	681S 0 0 D-5410	679S 0 0 E-4527	696C 0 0 E-4735	702U 0 0 E-5453	710A 0 0 D-4568	718T 0 0 E-5194	736B 0 0 D-4426	733T 0 0 E-3903	848A 0 0 D-4141	857U 0 0 D-1527	871A 0 0 E-4142	870U 0 0 D-3288	0
	674B 270. 30. D-1683	=ANIMAL NUMBER =INITIAL LUNG BURDEN (KBQ) =INITIAL LUNG BURDEN (KBQ/KG) =D=DEAD, E=EUTHANIZED DAYS AFTER EXPOSURE AT DEATH											

Figure 9. Experimental design for dose-response study of Beagle dogs exposed by inhalation to 3.0 μm AMAD aerosols of $^{238}PuO_2$ (Status as of 9-30-91).

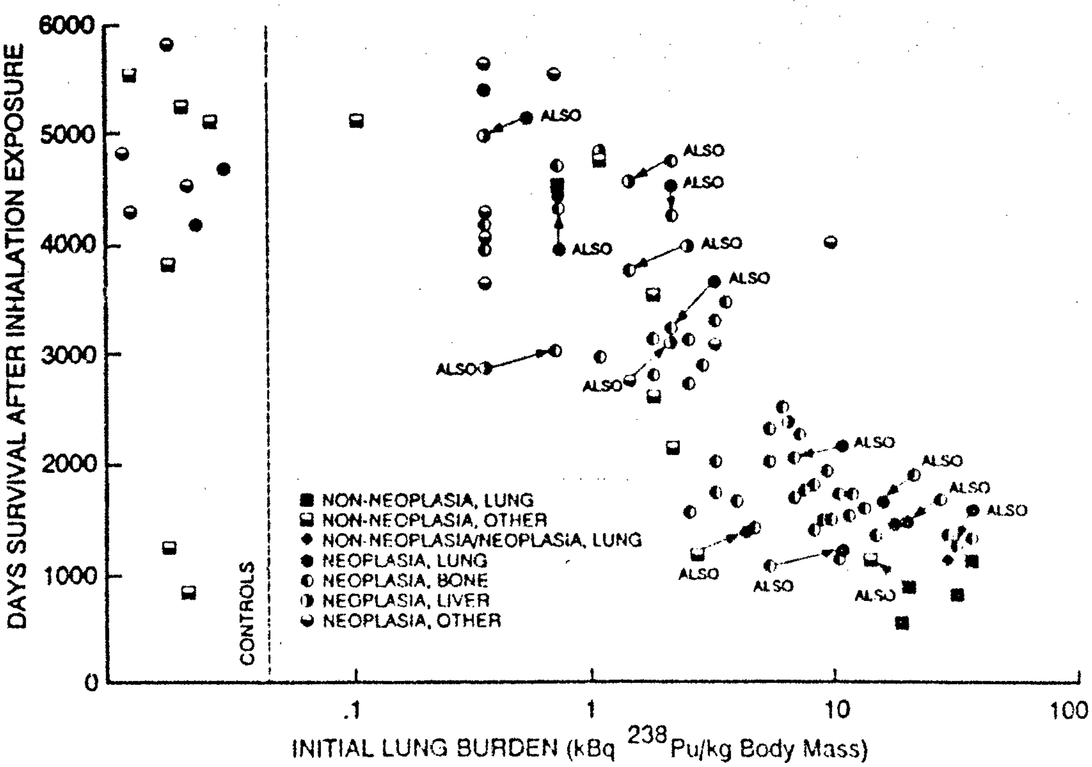

Figure 10. Survival of Beagle dogs that inhaled 1.5 μm AMAD monodisperse aerosols of $^{238}PuO_2$ (Status as of 9-30-91).

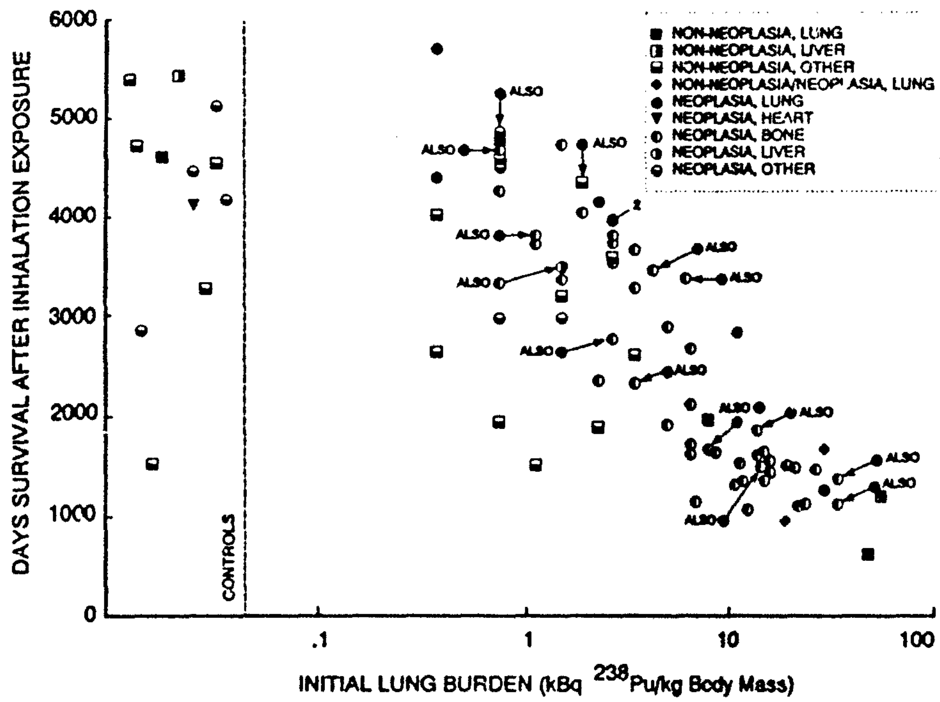

Figure 11. Survival of Beagle dogs that inhaled 3.0 μm AMAD monodisperse aerosols of $^{238}PuO_2$ (Status as of 9-30-91)

Major findings for all dogs in these studies are given in Tables 5 and 6. The last living dog, which had been exposed to a 1.5 μm aerosol of $^{238}PuO_2$, died during the past year. Dog 858A, a male, was euthanized with liver failure 5589 days after an inhalation exposure resulting in an ILB of 0.74 kBq per kg body mass. Several minor clinical problems were noted during the dog's lifetime. These problems included spondylosis, bilateral degenerative joint disease of the hips and elbows, a lingual fibropapilloma, a perianal squamous cyst, two episodes of tachypnea, radiographically increased pulmonary interstitial markings, and a slowly progressive heart murmur. Increased numbers of band neutrophils were noted about 16 months prior to death. Mild azotemia and mild anemia were noted about 3 months prior to death. The terminal illness resulting in euthanasia was manifested as lateral recumbency, anemia, thrombocytopenia, hyperglycemia, azotemia, hypoproteinemia, hyperbilirubinemia, hypocalcemia, and elevated liver enzymes.

At necropsy, the dog had myeloproliferative disease with involvement of the liver, spleen and multiple lymph nodes. The disease was manifested as marked, myeloid hypercellularity, a maturation arrest in the myeloid series, increased numbers of marrow blast cell, megakaryocytic hyperplasia, and increased numbers of immature megakaryocytes. Secondary to the tumor was a severe, multifocal and coalescent hepatic necrosis that resulted in the liver failure which produced most of the observed clinical signs. The anemia noted clinically was considered a myelophthisic anemia. A few thrombi were noted in vessels and sinusoids, and the thrombocytopenia noted clinically could be explained both by increased platelet consumption and decreased production in the neoplastic marrow. Renal failure noted clinically was attributed to the combined effects of moderate, multifocal, mesangioproliferative glomerulonephritis; mild, chronic pyelonephritis; and moderate bilirubinuria nephrosis. The slowly progressive heart murmur was attributed to moderate endocardiosis of the left atrioventricular valve. Incidental neoplasms included a thyroid follicular adenoma. Mild, multifocal, fibrosis of the lung may have been treatment-associated.

Table 5

Summary of Major Findings at Death in Dogs Exposed by Inhalation to Aerosols of Monodisperse 1.5 μm Particles of $^{238}PuO_2$ (Status as of 9-30-91)

	Number of Dogs	ILB[a] (kBq ^{238}Pu/kg Body Weight)	Survival Times (Days after Exposure)	Cumulative Radiation Dose to Lung (Gy)
^{238}Pu-Exposed				
Non-Neoplasia				
Lung	5[b]	0.74-37	536-4536	3.8-74
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	7[b,c]	0.11-14	1104-5123	0.20-35
Neoplasia				
Lung Injury with Lung Neoplasia	1	30	1107	47
Lung	13[c,d,f]	0.37-32	1245-5458	0.4-54
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	46[d,e]	0.37-37	1165-4761	1.3-54
Bone Marrow	0	--	--	--
Liver	7[e,f,g]	0.37-6.7	2416-5042	0.8-11
Other	8[g,h]	0.37-10	3131-5694	0.3-7.8
Control				
Non-Neoplasia				
Lung	0	--	--	--
Bone Marrow	0	--	--	--
Liver	1	--	3816	--
Other	5	--	820-5546	--
Neoplasia				
Lung Injury with Lung Neoplasia	0	--	--	--
Lung	2	--	4235,4746	--
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	4	--	4354-5879	--

[a]ILB = Initial lung burden based on whole-body counting of ^{169}Yb.
[b]One dog had pulmonary injury and immune hemolytic anemia.
[c]One dog had a lung tumor and disc protrusion.
[d]Eight dogs had lung and bone tumors.
[e]Three dogs had bone and liver tumors.
[f]One dog had lung and liver tumors.
[g]One dog had a liver tumor and gingival neoplasia.
[h]One dog had myeloproliferative disease.

Table 6

Summary of Major Findings at Death in Dogs Exposed by Inhalation to Aerosols of Monodisperse 3.0 μm Particles of $^{238}PuO_2$ (Status as of 9-30-91)

	Number of Dogs	ILB[a] (kBq ^{238}Pu/kg Body Weight)	Survival Times (Days after Exposure)	Cumulative Radiation Dose to Lung (Gy)
^{238}Pu-Exposed				
Non-Neoplasia				
Lung	4	0.74-56	631-4848	4.1-92
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	11[e,f]	0.37-3.3	1525-5788	0.3-8.7
Neoplasia				
Lung Injury with Lung Neoplasia	2	19,30	966,1683	35,74
Lung	21[b,d,e,f]	0.37-34	1181-5788	0.30-58
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	45[b,c]	0.74-34	1125-4815	1.0-53
Bone Marrow	0	--	--	--
Liver	1[c]	1.5	3566	4.0
Other	4[d]	0.74-1.5	3043-4950	1.0-4.3
Control				
Non-Neoplasia				
Lung	1	--	4626	--
Bone Marrow	0	--	--	--
Liver	1	--	5453	--
Other	5	--	1527-5410	--
Neoplasia				
Lung Injury with Lung Neoplasia	0	--	--	--
Lung	0	--	--	--
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	1	--	4141	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	4	--	2903-5194	--

[a]ILB = Initial lung burden based on whole-body counting of ^{169}Yb.
[b]Twelve dogs had bone and lung tumors.
[c]One dog had bone and liver tumors.
[d]One dog had lung and mammary tumors.
[e]One dog had ankylosing spondylosis and lung adenocarcinoma.
[f]One dog had disc protrusion and lung carcinoma.

c. Toxicity of Inhaled $^{239}PuO_2$ in Beagle Dogs. XIII:

i. Monodisperse 0.75 μm AMAD Particles.

ii. Monodisperse 1.5 μm AMAD Particles.

iii. Monodisperse 3.0 μm AMAD Particles.

Study Contact: F. F. Hahn

Studies of the long-term biological effects of ^{239}Pu are being conducted because ^{239}Pu is a major radionuclide in most nuclear fuel cycles and in the production of nuclear weapons. These studies also directly investigate the importance of uniform vs. non-uniform alpha irradiation of the lung. Young-adult dogs of both sexes inhaled one of three sizes of monodisperse aerosols of $^{239}PuO_2$; 0.75, 1.5, or 3.0 μm AMAD. Forty-eight dogs were exposed to 0.75 μm AMAD particles; 96 were exposed to 1.5 μm AMAD particles; 72 were exposed to 3.0 μm AMAD particles; and 36 dogs were exposed only to the aerosol vehicle. The initial pulmonary burdens ranged from 0.03 to 74 kBq/kg body mass. To assess the plutonium activity initially deposited in the lung, a short-lived, gamma-emitting radionuclide, ^{169}Yb, was incorporated into the PuO_2 aerosol, and whole-body counts were performed up to 120 days after exposure. A description of the ^{169}Yb counting technique for estimating initial pulmonary burdens of plutonium was reported previously (1979-80 Annual Report, LMF-84, pp. 132-140). The methods used to prepare the monodisperse aerosols and the aerosol exposure procedures were described in the 1976-77 Annual Report, LF-58, pp. 135-138. The experimental design charts in Figures 12-14 show the present status of these studies. The dogs in these studies are being maintained to study the biological effects that may occur throughout their lives, and the procedures for health evaluations of these animals have been described (1978-79 Annual Report, LF-69, pp. 134-140).

DESIGN KBQ/KG	A	B	C	D	E	F	G	H	I	J	K	L	MEAN KBQ/KG
5.2	963E 27. 2.3 E-2176	980T 34. 3.6 E-1579	997B 63. 5.9 D-1035	996U 19. 2.7 E-2446	1006B 25. 2.9 E-1961	1027U 56. 5.6 E-2779	1097E 32. 1.7 E-2251	1092S 56. 5.9 E-1371	1109B 70. 6.7 D-1520	1125S 44. 5.6 E-1280	1134C 67. 7.4 E-891	1142V 63. 7.0 E-1181	4.4
2.6	963F 17. 1.5 E-3302	982T 7.8 0.78 D-3748	990C 19. 2.0 D-2007	999S 19. 2.3 D-2886	1005C 24. 2.3 D-2089	1028U 32. 3.7 E-2742	1094C 23. 2.7 E-2031	1096S 14. 1.6 E-3115	1107A 44. 3.7 E-1757	1122T 32. 4.1 E-1525	1136A 67. 6.3 D-1467	1145T 18. 1.8 E-2563	2.7
1.1	970D 10. 0.96 E-3897	976T 7.4 0.70 D-4526	990A 17. 1.7 E-1718	1001T 23. 2.2 E-2081	1006A 14. 1.7 D-3370	1023W 19. 2.0 D-2741	1097C 14. 1.5 E-2343	1096U 7.4 0.89 E-3661	1100S 10. 1.0 E-3429	1121S 12. 1.4 E-2752	1130B 20. 1.9 E-3093	1143T 14. 1.6 D-2951	1.5
0.37	969A 8.5 0.85 E-4162	977S 4.8 0.47 E-4618	988C 3.3 0.37 E-3626	996T 2.6 0.30 E-4275	1005D 5.2 0.55 E-4171	1028S 3.3 0.37 D-4157	1096A 2.4 0.22 D-4488	1094T 4.1 0.37 D-3589	1111B 7.4 0.78 E-3375	1125T 6.3 0.78 D-3461	1134B 15. 1.5 E-3094	1143S 5.6 0.52 E-3970	0.59
CONTROL	961A 0 0 D-4977	980S 0 0 D-3609	992A 0 0 A-5106	999U 0 0 D-3906	1007C 0 0 D-1893	1022W 0 0 E-4411	1098A 0 0 E-4024	1095T 0 0 A-4877	1106A 0 0 A-4853	1121T 0 0 D-3349	1131D 0 0 E-4375	1146S 0 0 A-4694	0

963E =ANIMAL NUMBER
27. =INITIAL LUNG BURDEN (KBQ)
2.3 =INITIAL LUNG BURDEN (KBQ/KG)
E-2176 =D=DEAD, E=EUTHANIZED, A=ALIVE - DAYS AFTER EXPOSURE AT DEATH OR ON 9-30-91

Figure 12. Experimental design for dog study with 0.75 μm AMAD monodisperse particles of $^{239}PuO_2$ (Status as of 9-30-91).

DESIGN KBQ/KG	A	B	C	D	E	F	G	H	I	J	K	L	MEAN KBQ/KG
21	972A 210. 21. E-561	964S 280. 31. D-336	996A 190. 18. E-593	990U 250. 29. D-487	1015B 150. 17. D-399	1023X 93. 11. E-652	1097B 200. 21. E-278	1110U 250. 37. D-206	1117B 280. 29. D-221	1137S 340. 34. D-249	1134D 74. 7.0 E-152	1155S 300. 37. D-210	24
10	977B 130. 11. D-503	964T 48. 6.3 E-1377	995C 150. 15. D-1333	994S 100. 11. D-728	1027A 180. 17. D-852	1009T 63. 5.9 E-1939	1096C 140. 14. D-904	1101S 320. 32. E-347	1099B 170. 16. E-387	1141U 81. 12. D-793	1130A 41. 3.7 D-973	1155T 130. 19. E-522	14
5.2	976A 67. 5.2 D-1438	965S 63. 6.3 E-1981	997C 89. 8.5 D-1266	989T 48. 7.0 D-1684	1023B 56. 5.6 D-1787	1020T 48. 5.2 D-1134	1092S 110. 11. E-737	1099V 78. 8.9 E-947	1110B 130. 16. D-412	1141S 70. 7.0 D-345	1129A 23. 2.4 E-3052	1148U 48. 7.0 E-1540	7.4
2.6	970A 56. 5.6 D-1809	966T 37. 3.6 D-1802	995A 44. 4.4 E-2666	994T 41. 4.8 D-2013	1007A 25. 2.6 E-1941	1008S 41. 4.1 E-2269	1094B 12. 1.0 E-1647	1095S 70. 7.0 D-3204	1120A 37. 4.1 E-1713	1139U 33. 3.6 E-1745	1132C 27. 2.4 D-705	1160T 41. 4.8 E-1528	4.1
1.1	978B 8.9 1.0 E-4019	972S 14. 1.7 D-2148	999A 15. 1.9 E-4265	992T 11. 1.6 E-3068	1025D 16. 1.4 E-2414	1022T 16. 1.7 E-3535	1096D 8.1 0.78 E-2340	1099T 59. 7.0 A-4815	1099C 23. 2.2 D-1735	1130T 32. 3.7 E-1779	1129B 22. 2.1 D-862	1153T 17. 2.1 E-3366	2.3
0.37	970F 5.6 0.63 D-3945	969U 5.6 0.55 E-3633	992D 6.7 0.63 D-2315	986S 3.2 0.41 D-3783	1007B 15. 1.3 E-3778	1010T 5.2 0.52 D-1109	1092C 4.1 0.41 E-3915	1112W 34. 4.1 E-1086	1113A 9.3 0.96 E-4229	1134S 5.9 0.74 A-4688	1130C 16. 1.8 E-3633	1153S 4.1 0.44 A-4590	1.0
0.093	972D 1.3 0.15 D-5309	960U 3.4 0.37 E-4412	994B 2.3 0.23 A-5277	988U 2.3 0.26 A-5312	1017A 7.8 0.85 E-4860	1010W 1.7 0.16 A-5214	1097A 2.0 0.23 E-4643	1110S 13. 1.5 D-2380	1118A 3.8 0.35 E-4290	1146T 4.8 0.55 A-4610	1132D 2.1 0.22 A-4702	1154S 1.1 0.13 A-4591	0.41
0.0085	971C 0.74 0.089 A-5768	970S 2.7 0.28 E-4530	997A 0.70 0.067 E-4901	986S 0.78 0.081 D-3955	1014C 4.4 0.52 E-4705	1022V 0.25 0.027 D-4968	1095A 0.55 0.048 E-4516	1112U 5.6 0.59 A-4815	1108A 2.2 0.23 A-4808	1130S 1.2 0.15 D-4430	1131B 0.92 0.085 A-4702	1149T 0.92 0.12 A-4591	0.21
CONTROL	977A 0 0 E-4342	960T 0 0 A-5379	998A 0 0 A-5269	982S 0 0 E-4503	[illegible] 0 0 E-5216	1021S 0 0 A-5212	1093B 0 0 D-4441	1107S 0 0 A-4813	1109A 0 0 A-4806	1136S 0 0 A-4688	1131A 0 0 E-3472	1152S 0 0 A-4591	0
	972A 210. 21. E-561	=ANIMAL NUMBER =INITIAL LUNG BURDEN (KBQ) =INITIAL LUNG BURDEN (KBQ/KG) =D=DEAD, E=EUTHANIZED, A=ALIVE - DAYS AFTER EXPOSURE AT DEATH OR ON 9-30-91											

Figure 13. Experimental design for dog study with 1.5 μm AMAD monodisperse particles of $^{239}PuO_2$ (Status as of 9-30-91).

DESIGN KBQ/KG	A	B	C	D	E	F	G	H	I	J	K	L	MEAN KBQ/KG
21	964A 140. 14. E-702	981T 480. 41. D-256	984A 570. 52. D-116	1004S 420. 48. D-230	997D 240. 28. D-554	1034S 160. 21. D-506	1069A 590. 52. D-288	1101U 210. 20. E-727	1100D 270. 25. D-471	1138T 220. 33. E-631	1122B 620. 74. E-105	1152V 440. 44. E-427	37
10	963A 52. 4.4 D-1635	977T 150. 19. E-589	980A 200. 19. D-656	1007S 93. 12. D-781	1001A 270. 26. E-636	1029S 110. 10. D-733	1069B 240. 21. D-754	1105T 130. 13. E-1015	1099A 230. 21. E-1098	1137U 140. 13. E-1005	1117D 200. 21. E-525	1149S 140. 16. E-1355	16
5.2	966A 24. 2.1 E-1578	977U 180. 17. E-618	989A 100. 13. E-1525	1005S 78. 8.9 D-1844	1000B 140. 13. E-1138	1023U 41. 5.2 E-1987	1071A 110. 11. E-1434	1101T 78. 9.3 E-1043	1105A 96. 9.3 E-1055	1137T 89. 8.9 D-1422	1124B 230. 21. E-454	1147U 81. 8.9 E-1257	10
2.6	965A 13. 1.1 E-4789	980V 89. 10. D-876	986A 30. 2.7 E-2527	1008T 34. 4.4 D-2900	1095B 34. 3.7 E-3497	1023V 27. 3.1 E-2451	1070A 63. 5.9 E-1648	1106S 27. 2.7 E-2387	1097D 37. 3.7 E-1458	1139T 41. 4.1 E-1561	1117C 67. 5.9 E-1925	1152U 37. 4.1 E-2798	4.4
1.1	960A 9.3 0.92 E-3746	981S 14. 1.4 E-4461	988D 17. 1.4 E-3626	1005U 10. 1.1 E-2820	999B 21. 2.3 E-4129	1034T 5.6 0.85 E-4355	1070B 41. 3.6 E-3185	1099S 8.5 1.1 D-2429	1104A 44. 4.1 E-2096	1139S 15. 1.4 A-4618	1121B [illegible] [illegible] E-2450	1160V 20. 2.0 D-2955	1.9
0.37	963B 4.9 0.41 D-5227	980U 17. 1.5 E-2871	982A 7.0 0.67 E-4145	1009S 4.1 0.37 E-3660	994D 4.6 0.44 E-4410	1033U 2.0 0.22 D-4536	1072B 14. 1.3 E-3354	1096T 7.8 0.70 A-4864	1101A 12. 1.1 E-3321	1138S 4.1 0.52 E-4397	1121C 10. 0.96 E-3952	1160S 18. 2.0 E-3290	0.85
CONTROL	961D 0 0 E-4473	975S 0 0 E-4567	988D 0 0 A-5306	999T 0 0 D-4971	994C 0 0 E-4587	1033S 0 0 A-5155	1072C 0 0 D-1950	1104T 0 0 A-4864	1108C 0 0 A-4863	1128U 0 0 E-3481	1122C 0 0 A-4770	1132T 0 0 A-4556	0
	964A 140. 14. E-702	=ANIMAL NUMBER =INITIAL LUNG BURDEN (KBQ) =INITIAL LUNG BURDEN (KBQ/KG) =D=DEAD, E=EUTHANIZED, A=ALIVE - DAYS AFTER EXPOSURE AT DEATH OR ON 9-30-91											

Figure 14. Experimental design for dog study with 3.0 μm AMAD monodisperse particles of $^{239}PuO_2$ (Status as of 9-30-91).

Descriptions of the major clinical and pathology findings for each dog have been included in the annual report for the year in which the dogs died; survival data are summarized in Figures 15-17. Exposure information and dosimetry results for each dog are given in Appendix A.

During the past year, 9 dogs died: four were dogs exposed to the 1.5 μm AMAD particles; two were dogs exposed to the 3.0 μm particles; and three were control dogs exposed to the aerosol vehicle. Summaries of the major clinical and pathological findings are presented below. As of September 30, 1991, 200 exposed and 19 control dogs from these three studies have died. The major findings at death from all of these dogs are summarized in Tables 7-9. We continue to observe the 16 plutonium-exposed dogs and 17 control dogs that remain alive at 13-to-15 yr after exposure.

Four dogs that inhaled 1.5 μm AMAD aerosols of $^{239}PuO_2$ died during the past year. Fourteen dogs that inhaled $^{239}PuO_2$ in this size aerosol remained alive on September 30, 1991.

Dog 1097A, a male, was euthanized 4643 days after an inhalation exposure that resulted in an ILB of 0.23 kBq per kg body mass. The dog had several clinical problems during its lifetime. A moderate to marked pulmonary interstitial infiltrate was noted twice, and a mild increase in pulmonary interstitial markings was noted once. Because of confirmed hypothyroidism, the dog was placed on synthroid 60 months before death. Cardiomegaly was first noted about 41 months before death. About 30 months before death, the dog developed a transient episode of hemorrhagic enteritis. Renal disease, noted 4 months before death, was persistent. The terminal illness began with the notation of a lung tumor about 8 months before death. The pulmonary neoplasm grew progressively and resulted in euthanasia.

At necropsy, a primary, papillary adenocarcinoma was found in the right diaphragmatic lung lobe. The adenocarcinoma metastasized within the right diaphragmatic lung lobe, and a papillary adenocarcinoma of the right cardiac lung lobe was also considered a metastasis. A papillary adenocarcinoma of the left apical-cardiac lung

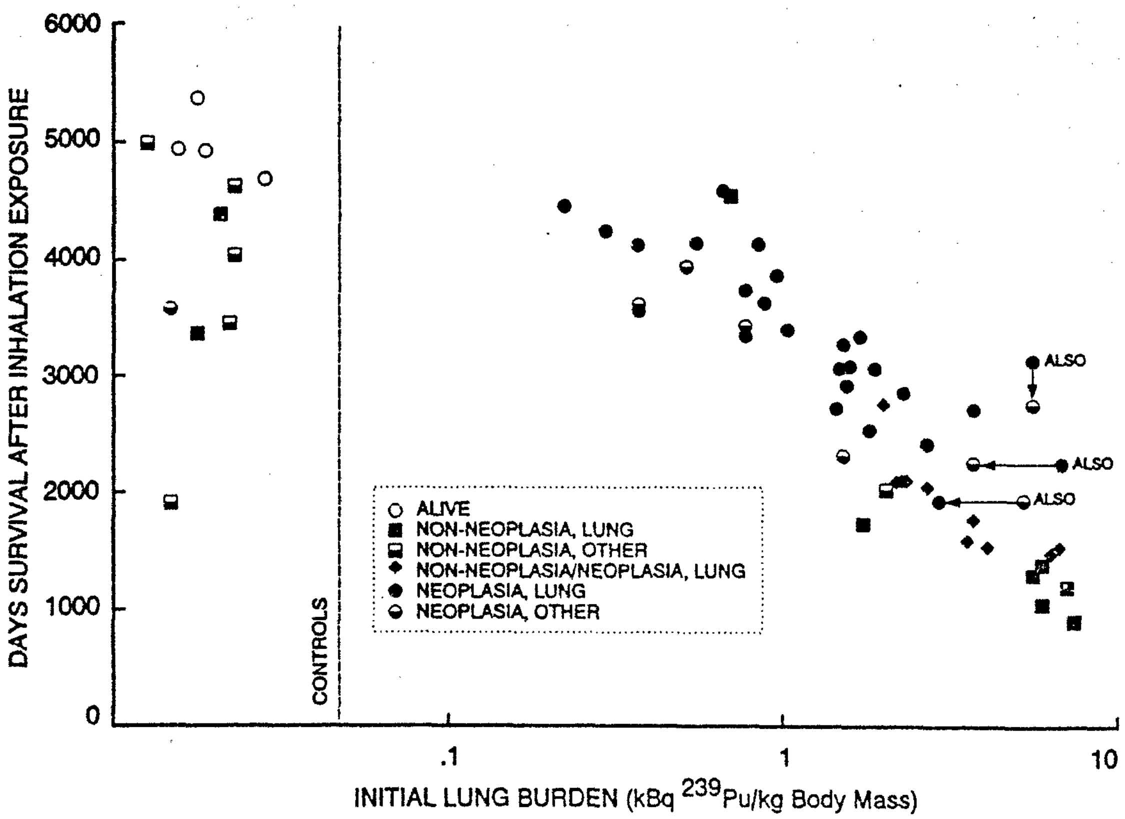

Figure 15. Survival of dogs that inhaled 0.75 μm AMAD monodisperse particles of $^{239}PuO_2$ (Status as of 9-30-91).

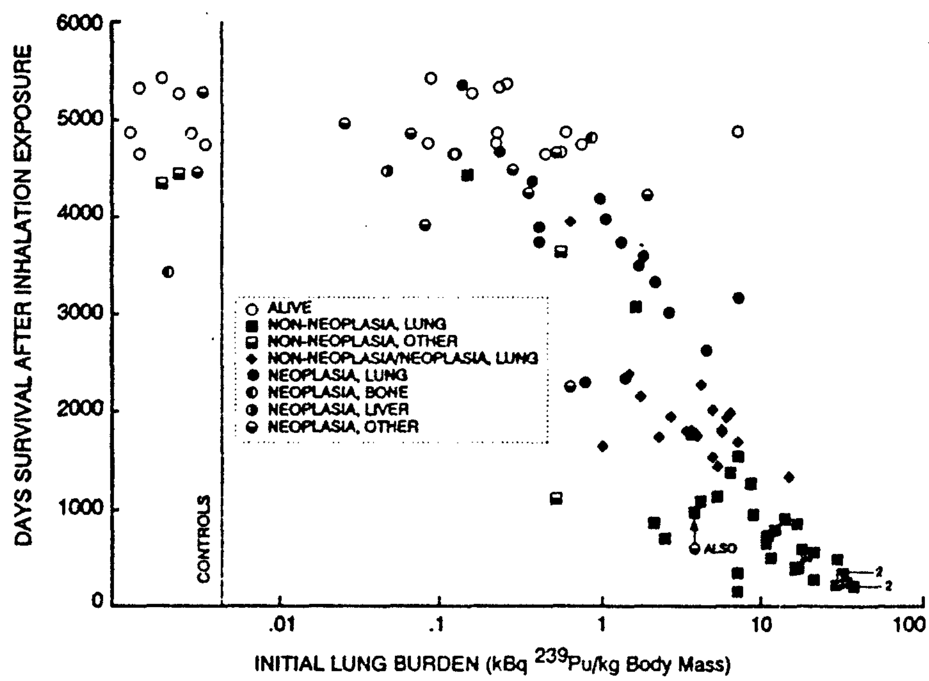

Figure 16. Survival of dogs that inhaled 1.5 μm AMAD monodisperse particles of $^{239}PuO_2$ (Status as of 9-30-91). Note that dogs having lung neoplasia as an incidental finding are designated as "non-neoplasia/neoplasia lung." Dogs in which lung neoplasia was a major finding are designated as "neoplasia, lung."

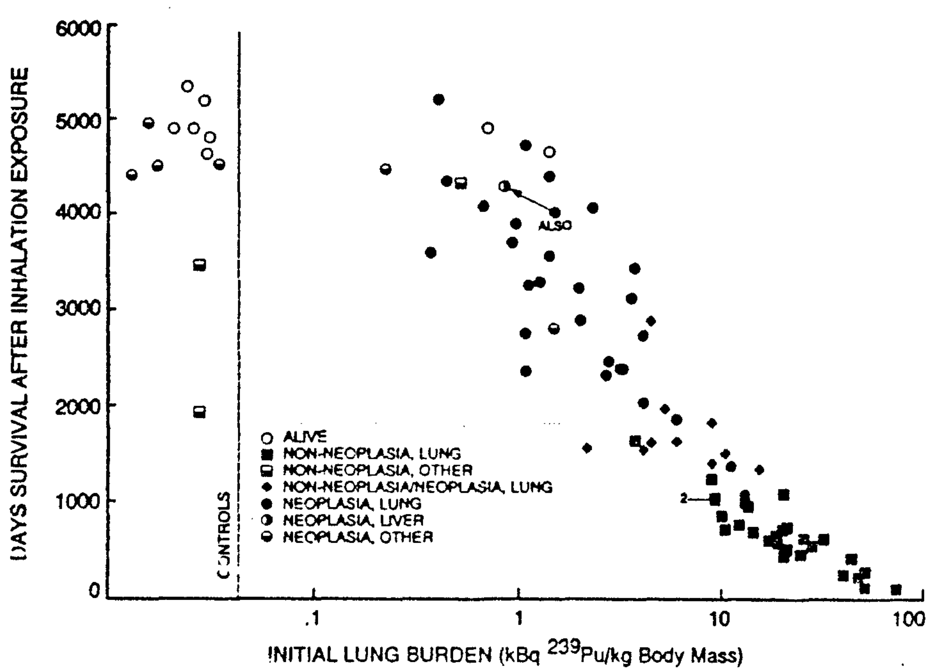

Figure 17. Survival of dogs that inhaled 3.0 μm AMAD monodisperse particles of $^{239}PuO_2$ (Status as of 9-30-91).

Table 7

Summary of Major Findings at Death in Dogs Exposed by Inhalation to Aerosols of Monodisperse 0.75 μm Particles of $^{239}PuO_2$ (Status as of 9-30-91)

	Number of Dogs	ILB[a] (kBq ^{239}Pu/kg Body Weight)	Survival Times (Days after Exposure)	Cumulative Radiation Dose to Lung (Gy)
^{239}Pu-Exposed				
Non-Neoplasia				
Lung	7	0.7-7.4	891-4526	6.0-41
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	1	2.0	2007	15
Neoplasia				
Lung Injury with Lung Neoplasia	10	2.0-6.7	1467-2741	13-31
Lung	26[b,c,d]	0.22-5.6	1961-4618	2.0-26
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	7[b,c,d]	0.30-5.6	1961-3970	2.8-23
Control				
Non-Neoplasia				
Lung	2	--	3349,4375	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	5	--	1893-4977	--
Neoplasia				
Lung Injury with Lung Neoplasia	0	--	--	--
Lung	0	--	--	--
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	1	--	3609	--

[a]ILB = Initial lung burden based on whole-body counting of ^{169}Yb.
[b]One dog had a lung tumor and a brain meningioma.
[c]One dog had a lung tumor and a fibrosarcoma in the mediastinum.
[d]One dog had a lung tumor and a muscle fibrosarcoma.

Table 8

Summary of Major Findings at Death in Dogs Exposed by Inhalation to Aerosols of Monodisperse 1.5 μm Particles of $^{239}PuO_2$ (Status as of 9-30-91)

	Number of Dogs	ILB[a] (kBq ^{239}Pu/kg Body Weight)	Survival Times (Days after Exposure)	Cumulative Radiation Dose to Lung (Gy)
^{239}Pu-Exposed				
Non-Neoplasia				
Lung	34[b]	1.6-37	152-3068	5.6-59
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	3	0.15-0.56	1109-4430	1.5-4.3
Neoplasia				
Lung Injury with Lung Neoplasia	19	0.63-15	1333-3945	4.9-49
Lung	16[c]	0.15-7.0	2340-5309	1.5-51
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	1	0.85	4860	7.1
Bone Marrow	0	--	--	--
Liver	1	0.48	4516	0.40
Other	10[b,c]	0.067-3.7	973-5309	0.55-15
Control				
Non-Neoplasia				
Lung	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	3	--	4342-5216	--
Neoplasia				
Lung Injury with Lung Neoplasia	0	--	--	--
Lung	0	--	--	--
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	1	--	3472	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	1	--	4503	--

[a]ILB = Initial lung burden based on whole-body counting of ^{169}Yb.
[b]One dog had lung injury and a kidney carcinoma.
[c]One dog had lung carcinoma and laryngeal carcinoma.

Table 9

Summary of Major Findings at Death in Dogs Exposed by Inhalation to Aerosols of Monodisperse 3.0 μm Particles of $^{239}PuO_2$ (Status as of 9-30-91)

	Number of Dogs	ILB[a] (kBq ^{239}Pu/kg Body Weight)	Survival Times (Days after Exposure)	Cumulative Radiation Dose to Lung (Gy)
^{239}Pu-Exposed				
Non-Neoplasia				
Lung	29	3.7-74	105-1658	24-77
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	2[c]	0.41,0.52	4397,5227	4.3,5.6
Neoplasia				
Lung Injury with Lung Neoplasia	10	2.2-16	1355-2900	13-84
Lung	28[b,c]	0.37-13	1108-5227	3.9-85
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	1[b]	0.85	4355	9.4
Other	2	0.22,1.5	2871,4536	2.5,13
Control				
Non-Neoplasia				
Lung	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	3	--	1950-4971	--
Neoplasia				
Lung Injury with Lung Neoplasia	0	--	--	--
Lung	0	--	--	--
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	3	--	4473-4587	--

[a]ILB = Initial lung burden based on whole-body counting of ^{169}Yb.
[b]One dog had lung and liver tumors.
[c]One dog had congestive heart failure and lung carcinoma.

lobe was considered primary, but incidental. A unilateral, adrenal, cortical carcinoma metastasized to the left diaphragmatic lung lobe. Plutonium-associated lesions included marked atrophy of the tracheobronchial lymph node and multifocal, moderate, pulmonary interstitial fibrosis with associated alveolar epithelial cell hypertrophy and hyperplasia and mild infiltration of mononuclear inflammatory cells. Clinical hypothyroidism was attributed to marked thyroid atrophy and mild, lymphoplasmacytic thyroiditis. Clinical renal disease was attributed to moderate, chronic pyelonephritis.

Dog 1130S, a female, was found dead 4430 days after an inhalation exposure which resulted in ILB of 0.15 kBq/kg body mass. This dog had few clinical problems during its lifetime. Radiographically, increased interstitial markings were noted in the lungs four times. The dog had clinical hypothyroidism which was confirmed 72 mo before death. Spondylosis was present at $C_{6\text{-}7}$, $T_{12\text{-}13}$, $L_{1\text{-}2}$, and $L_{4\text{-}5}$. On the day of death, the dog was dyspneic and tachypneic.

At necropsy, abundant fluid was in the thoracic cavity and contained frequent brownish-yellow granules ("sulfur granules") consistent with infection due to *Nocardia* or *Actinomyces*. Pulmonary lesions were manifested as moderate, chronic-active, septic pleuropneumonia characterized by moderate to marked, proliferative pleuritis; interstitial pneumonia; and pyothorax. A focus of adenomatous hyperplasia was noted in the left diaphragmatic lung lobe. Moderate atrophy of the tracheobronchial lymph node was considered exposure related. Clinical hypothyroidism was attributed to severe, idiopathic thyroid atrophy.

Dog 972D, a male, was found dead 5309 days after an inhalation exposure that resulted in an ILB of 0.15 kBq per kg body mass. Clinically, a few minor problems were noted during the dog's lifetime. These included decreased renal function which was noted 24 mo before death. The dog also had degenerative joint disease which involved both hips and the left elbow. Spondylosis and narrowed disc spaces were noted at $C_{6\text{-}7}$, T_{13}-L_1, and $L_{1\text{-}5}$. The terminal illness presented 23 days before death with clinical signs of anorexia, tachypnea, and moist lung sounds.

At necropsy, all lung lobes were heavy, dark red, wet, and consolidated. Approximately 300 mls of serosanguineous fluid were in the thoracic cavity. Microscopically, a metastatic papillary adenocarcinoma was found in the lung, tracheobronchial lymph node, mediastinal lymph node, sternal lymph node, hepatic lymph node, *tunica muscularis* of the esophagus, and vertebrae. The metastatic adenocarcinoma was consistent with a neoplasm of pulmonary origin, but the primary was not found. In the larynx, a papillary neoplasm protruded into the airway lumen from the stalk of the epiglottis and undoubtedly contributed to respiratory failure in this dog. Microscopically, the laryngeal neoplasm was a squamous cell carcinoma. Renal lesions included multifocal, moderate glomerulonephritis; a fibroma; and multifocal, mild, chronic pyelonephritis. These renal lesions were considered responsible for the decreased renal function noted clinically.

Dog 1022V, a female, was found dead 4968 days after an inhalation exposure that resulted in ILB of 0.026 kBq per kg body mass. A few minor clinical problems were noted during the lifetime. Leukopenia and polycythemia were occasionally observed and spondylosis developed as the dog aged. Tachypnea, which was first observed 132 mo before death, was recurrent. An increased interstitial lung pattern was first seen about 56 mo before death, and right-sided cardiomegaly was first noted about 55 mo before death.

At necropsy, approximately 500 mls of fluid were in the thoracic cavity, and the fluid was considered responsible for death by respiratory failure. The hydrothorax was secondary to obstruction of pulmonary lymphatics by tumor emboli originating from a simple, solid carcinoma of the left cranial mammary chain. The mammary carcinoma had metastasized to the sternal lymph node. Moderate atrophy of the tracheobronchial lymph node was considered related to $^{239}PuO_2$. A pituitary chromophobe adenoma and a thyroid microfollicular adenoma were considered incidental due to the absence of associated clinical signs.

Two dogs that inhaled $^{239}PuO_2$ in 3μm AMAD aerosols died during the past year. Two dogs exposed to this size aerosol were alive on September 30, 1991.

Dog 1138S, a female, was euthanized with heart failure 4397 days after an inhalation exposure which resulted in an ILB of 0.52 kBq/kg body mass. Non-progressive radiation pneumonitis/pulmonary fibrosis was first noted more than 48 mo before death. A grade III/VI heart murmur was first detected 41 days after the diagnosis of radiation pneumonitis. An episode of liver disease manifested as leukocytosis with concomitant elevation of SAP, SGPT, and bilirubin developed approximately 36 mo before death. Heart failure developed 277 days before death and was progressive. Euthanasia was performed because of uncontrollable ascites.

Necropsy findings were consistent with death due to heart failure. Cardiac alterations were manifested as bilateral ventricular dilation, a "jet lesion" on the right AV valve, and alterations of myocardial structure classified as dilatative cardiomyopathy and characterized by disorganization, anisokaryosis, degeneration, and steatosis of the myocardium. Ascites was considered secondary to right-sided heart failure. Pulmonary manifestations of left-sided heart failure were consistent with chronic cardiogenic edema but some of the interstitial fibrosis, alveolar epithelial hyperplasia, and squamous metaplasia was considered exposure related. Severe atrophy of the tracheobronchial lymph node was typical of $^{239}PuO_2$ exposure. A benign granulosa cell tumor was in an ovary and a complex tubular adenocarcinoma was in the L_2 mammary gland. Consistent with the history of prior liver disease, the liver had mild, telangiectasia, and moderate, biliary hyperplasia with frequent interstitial fibrosis which sometimes progressed to bridging fibrosis.

Dog 963B, a male, was found dead 5227 days after an inhalation exposure that resulted in an ILB of 0.41 kBq per kg body mass. The dog had a long clinical history of heart disease manifested as cardiomegaly and a heart murmur of increasing severity. The third digit of the right front foot was surgically amputated 36 mo before death as a result of chronic-active inflammation. Multiple skin masses were removed 24 mo before death and included multiple foci of adenomatous hyperplasia and two sebaceous adenomas. A lipoma was removed from the sternum 12 mo before death. Spondylosis of T_{11-12}, T_{13}-L_1, and L_{3-5} and a mediastinal density were noted 102 days before death. The dog developed ascites 10 days before death. The BUN was elevated the following day.

At necropsy, the dog had multiple manifestations of heart failure. These included ascites, hydrothorax, chronic passive congestion of the liver, cardiomegaly, moderate endocardiosis of the left and right atrioventricular valves, and a chronic right ventricular infarct. Diseases contributing to the impairment of gas exchange were 1) moderate, pulmonary interstitial fibrosis with associated alveolar epithelial cell hypertrophy and hyperplasia and alveolar histiocytosis (consistent with radiation pneumonitis); and 2) a primary pulmonary adenocarcinoma of the left diaphragmatic lung lobe with metastasis to the right cardiac lung lobe. Severe atrophy was in the tracheobronchial lymph node and was typical of $^{239}PuO_2$ exposure. An adenoma of the *pars intermedia* was in the pituitary.

Three dogs that served as controls for these studies died during the past year. As of September 30, 1991, 17 control dogs remained alive in the three studies of $^{239}PuO_2$ in young adult dogs.

Dog 1131D, a male control, was euthanized 4375 days after inhalation exposure to the vector aerosol. Persistent tachypnea was first noted 96 mo before death. An increase in the interstitial lung pattern was first noted approximately 72 mo before death. The dog was diagnosed with bronchitis 11 days before death. Three days later, the dog was found to have a bilateral pulmonary infiltrate, cardiomegaly, and a mass in the left apical lung lobe. The dog was euthanized after he failed to respond to antibiotic therapy.

At necropsy, the dog had a collapsed trachea; moderate, chronic-active tracheitis with focal squamous metaplasia and multifocal ulceration; bronchiectasia; and marked, chronic-active bronchopneumonia with syncytia formation and *bronchiolitis obliterans*. Lesions secondary to the bronchopneumonia included dilation of the right ventricle of the heart, eversion of the *sacculus laryngis*, hyperplasia of the myeloid series of the bone marrow, and suppurative lymphadenitis of multiple lymph nodes.

Dog 1010A, a male control, was euthanized with seizures 5216 days after exposure to the vector aerosol. The dog had several minor clinical problems during its lifetime. These included a transiently elevated SGPT more than 120 mo before death. A mildly elevated BUN was noted twice, 60 mo and 12 mo before death. A heart

murmur was noted approximately 45 mo before death. Dental disease was also present. The dog suddenly developed *status epilepticus* 2 days before death. Because seizures recurred each time the dog recovered from treatment-associated anesthesia, the dog was euthanized.

At necropsy, an astrocytoma of the anterior left cerebrum was considered responsible for the seizures. An anaplastic focus in the prostatic urethra was interpreted as an *in situ* and invasive transitional cell carcinoma of the prostatic urethra.

Dog 999T, a female control, died 4972 days after exposure to the vector aerosol. The dog had a few clinical problems during its lifetime. These included medial patellar luxation, degenerative joint disease of the left stifle, a grade II-III/VI systolic heart murmur, spondylosis of T_{13}-L_1, L_{2-3}, L_7-S_1, and herniation of an intervertebral disc at L_{2-3}. Glaucoma was noted in the right eye 9 mo before death. The right eye was enucleated 43 days later, and an ocular malignant melanoma was found on histopathologic examination. Radiographs suggested the presence of a pulmonary nodule 13 days before death. The dog was anesthetized for follow-up radiographs on the day of death, anesthetic recovery was difficult, and the dog was found dead later that day.

At necropsy, the immediate cause of death was attributed to acute, fibrinosuppurative bronchopneumonia, consistent with aspiration pneumonia, which was primarily localized to the left cardiac lung lobe. The ocular malignant melanoma had produced widespread metastases which undoubtedly predisposed this dog to aspiration pneumonia. Metastases were found in the lung, liver, pancreas, kidney, ovary, tracheobronchial lymph node, sternal lymph node, femur, vertebra, rib, adrenal gland, and pituitary. A granulosa cell tumor was in one ovary, and solid and microfollicular adenomas were in the left thyroid.

d. Toxicity of ^{144}Ce Inhaled in a Relatively Insoluble Form by Immature Beagle Dogs. XX.

Study Contact: B. B. Boecker

Immature Beagle dogs (3 mo old) received single, brief inhalation exposures to ^{144}Ce in fused aluminosilicate particles as part of the ITRI studies on the effects of age at exposure on the resulting dose-response relationships, and are being followed for life-span observations. The study is comprised of 49 dogs that inhaled graded levels of ^{144}Ce, resulting in ILB that ranged from 0.00015-5.2 MBq/kg body weight (0.004-140 μCi/kg), and five control dogs that inhaled fused aluminosilicate particles without ^{144}Ce. The exposures took place in 1972, 1973 and 1976. Specific details on experimental design considerations, metabolism and dosimetry of the inhaled ^{144}Ce, and early occurring biological effects were presented in previous annual reports from this Institute, especially in LF-45 (1981-1972), LF-46 (1972-1973), and LF-49 (1973-1974).

Annual summaries for this study have also been included in all other annual reports to the present time. The current status of this study is shown in the experimental design chart given in Figure 18. Exposure information and dosimetry results are given for each dog in Appendix A. Survival data for dogs in this study are summarized graphically in Figure 19. During the past year, one ^{144}Ce-exposed dog died. A summary of the major clinical and pathological findings is presented below. As of September 30, 1991, 48 ^{144}Ce-exposed dogs and all five control dogs have died or have been euthanized. A summary of the major findings in these dogs at death is given in Table 10. Observations continue on the one ^{144}Ce-exposed dog remaining alive at about 15 yr after exposure.

DESIGN MBQ/KG	A	B	C		D	E	MEAN MBQ/KG
3.7		675B 11. 4.4 D-95	671C 13. 3.1 D-121	673D 5.9 2.7 D-66	1022U 14. 5.2 D-91		3.7
2.8		672B 8.5 2.4 E-689	673C 5.2 2.6 D-511	672U 6.7 1.9 E-618	1027B 8.5 2.9 D-738	1024D 10. 2.7 E-700	2.5
1.9	629A 3.7 1.4 E-2666	675T 3.4 1.8 E-1227	672C 5.7 1.9 D-1732		1033T 3.5 1.4 E-3452	1026A 6.7 2.0 E-1314	1.5
0.93	627B 3.1 0.89 E-2341	673B 1.6 0.78 E-4841	673A 1.6 0.59 E-1326		1022S 4.1 1.3 D-2887	1019A 4.8 1.4 D-1413	1.0
0.46	630B 0.96 0.34 D-4674	671B 1.1 0.41 E-4266	672A 1.5 0.44 D-1520		1021V 2.1 0.67 E-2813	1033B 1.3 0.44 E-2772	0.44
0.22	630A 0.85 0.32 E-5387	671T 0.20 0.12 D-4715	675B 0.48 0.19 D-3835		1023S 0.59 0.25 E-3597	1016B 0.59 0.18 A-5521	0.19
0.044	624D 0.30 0.11 E-5298	674T 0.067 0.032 E-5905	671B 0.22 0.059 E-5932		1018U 0.15 0.037 D-5390	1017B 0.20 0.052 E-5025	0.059
0.0085	623A 0.041 0.010 E-5442	649U 0.019 0.0063 E-4289	668A 0.016 0.0052 E-5803		1021T 0.078 0.026 E-4614	1014B 0.027 0.0070 D-3005	0.011
0.0017	624C 0.0047 0.0023 E-3270	679B 0.0015 0.00089 E-5106	671A 0.0089 0.0033 D-4156		1017S 0.014 0.0044 E-4397	1021A 0.0074 0.0019 D-3665	0.0026
0.00033	624A 0.0018 0.00048 E-4745	663V 0.0004 0.00015 D-5338	671D 0.0006 0.00022 E-5513		1034U 0.0009 0.00032 E-5081	1013A 0.0012 0.00041 D-3670	0.00032
CONTROL	623B 0 0 E-4203	669B 0 0 E-4213	668B 0 0 D-3362		1013B 0 0 D-4015	1016A 0 0 E-1378	0
	629A 3.7 1.4 E-2666	=ANIMAL NUMBER =INITIAL LUNG BURDEN (MBQ) =INITIAL LUNG BURDEN (MBQ/KG) =D=DEAD, E=EUTHANIZED, A=ALIVE-DAYS AFTER EXPOSURE AT DEATH OR ON 9-30-91					

Figure 18. Experimental design for studying the effects of ^{144}Ce in fused alulminosilicate particles inhaled by immature (3 mo old) Beagle dogs (Status as of 9-30-91).

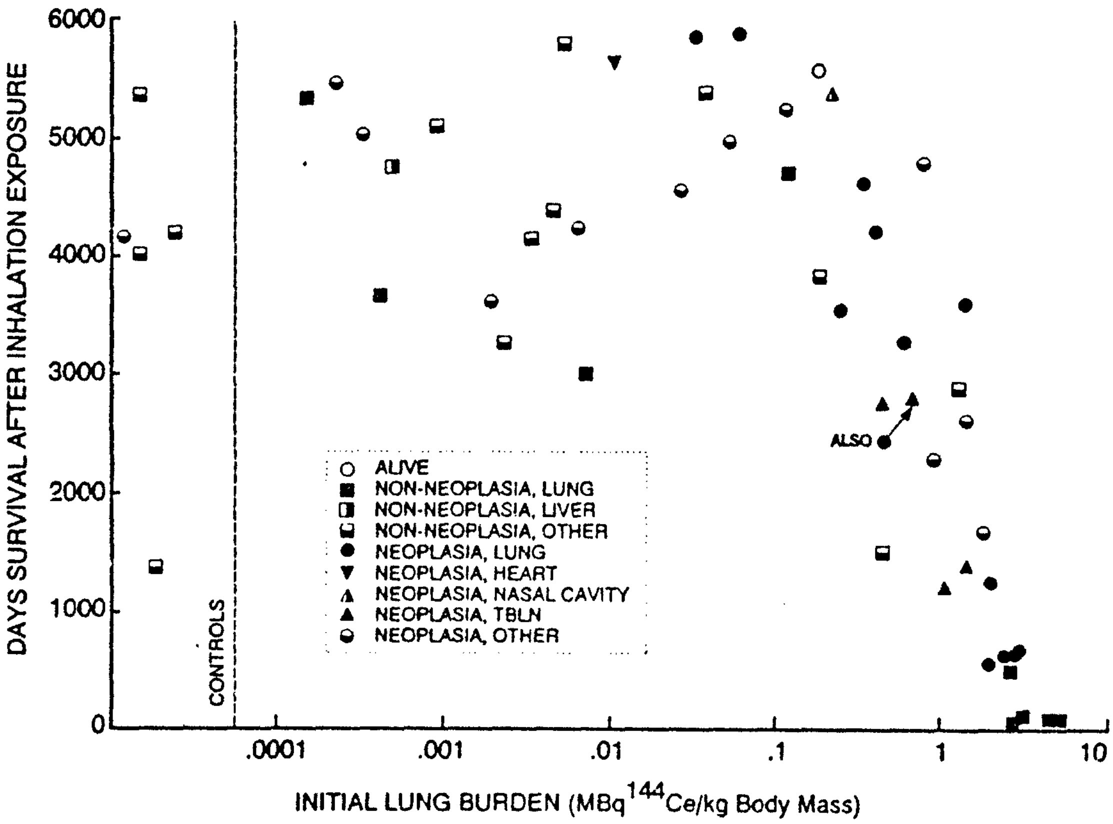

Figure 19. Relationships between ILB of of ^{144}Ce and survival time for Beagle dogs that inhaled ^{144}Ce in fused aluminosilicate particles when they were immature (3 mo old) (Status as of 9-30-91).

Dog 1018U, a female, was found dead 5390 days after exposure to an aerosol of ^{144}Ce in fused aluminosilicate particles that resulted in an ILB of 0.037 MBq per kg body mass. The dog had several minor clinical problems during its lifetime. These included three episodes of leukocytosis, an episode of rhythmic asystole, endometritis, and spondylosis of the C_{6-7} and L_{3-4} vertebrae. She had an inguinal hernia repair performed 139 days prior to death, and a tooth extraction was performed 72 days prior to death. Seizures were noted twice, at 11 days and 19 mo prior to death. The day before death, the dog had azotemia, hyperphosphatemia, hypocalcemia, hypoalbuminemia, increased serum creatinine, increased serum alkaline phosphatase, and leukocytosis. A grade IV/VI heart murmur appeared suddenly the day before death.

At necropsy, the dog had moderate, diffuse, fibrinosuppurative, interstitial pneumonia with fibrinosuppurative alveolitis. The dog also had moderate, nonsuppurative, interstitial nephritis, which was considered the primary cause of death. Debilitation, hypoalbuminemia, hyperphosphatemia, and uremia most likely predisposed this dog to the development of interstitial pneumonia. Decreased cardiac function was considered a major contributing disease, and while associated with marked hepatic congestion, the only cardiac lesion present microscopically was mild, localized, nonsuppurative myocarditis. Neither the grossly observed mild, localized endocardiosis nor the microscopically observed myocarditis seemed sufficient to explain the decreased cardiac function. Pulmonary hypertension secondary to the interstitial pneumonia may have produced secondary cardiac failure. An adenoma of the exocrine pancreas was an incidental finding at necropsy. Bilateral cortical adenomas were in the adrenal gland.

Table 10

Summary of Major Findings at Death in Immature (3 mo old) Dogs Exposed by Inhalation to ^{144}Ce in Fused Alumonisilicate Particles (Status as of 9-30-91)

	Number of Dogs	ILB[a] (MBq ^{144}Ce/kg Body Weight)	Survival Times (Days after Exposure)	Cumulative Radiation Dose to Lung (Gy)
^{144}Ce-Exposed				
Non-Neoplasia				
Lung	9	.00015-5.2	66-5338	0.017-270
Bone Marrow	0	--	--	--
Liver	1	.00048	4765	0.054
Other	9	.00089-1.3	1520-5802	0.11-150
Neoplasia				
Lung Injury with Lung Neoplasia	0	--	--	--
Lung	13[b]	.032-2.9	618-5932	2.9-310
Nasal Epithelium	1	0.22	5387	33
TBLN	4[b]	0.44-1.4	1227-2813	51-180
Heart	0	--	--	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	12	.00022-1.8	1732-5642	0.024-220
Control				
Non-Neoplasia				
Lung	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	4	--	1378-5362	--
Neoplasia	0	--	--	--
Lung Injury with Lung Neoplasia	0	--	--	--
Lung	0	--	--	--
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	1	--	4213	--

[a]ILB = Initial Lung Burden
[b]One dog had lung and TBLN tumors.

e. Toxicity of $^{239}PuO_2$ in Immature Beagle Dogs. XII.

Study Contact: R. A. Guilmette

As part of the ITRI studies on the effects of age at exposure on the resulting dose-response relationships, immature Beagle dogs (3 mo old at exposure) received single, brief inhalation exposures to a monodisperse aerosol of $^{239}PuO_2$ (1.5 μm AMAD) and are being followed for life-span observations. The experimental design consists of blocks of 12 dogs, each exposed to graded activity levels of ^{239}Pu that ranged from 20.7 to 0.0085 kBq/kg body mass; there were eight activity levels, with a total of 96 exposed dogs. Twelve control dogs exposed only to the aerosol vehicle were also included in the experiment. Two blocks of dogs were exposed in 1978. After a 2-yr break in exposures because of a colony outbreak of parvovirus enteritis, exposures were resumed in 1980 and continued through 1982. Specific details on experimental design considerations, metabolism and dosimetry of the inhaled ^{239}Pu, and early occurring biological effects have been presented in previous annual reports from this Institute, especially in LF-69, LMF-102, LMF-113, LMF-114, and LMF-115. Annual summaries for this study have also been included in all other annual reports to the present time.

The current status of this study is shown in the experimental design chart given in Figure 20. Exposure information and dosimetry results are given for each dog in Appendix A. Survival data for dogs in this study are summarized graphically in Figure 21. During the past year, six Pu-exposed dogs died; no control dogs died. Summaries of the major clinical and pathological findings are presented below. As of September 30, 1991, there were 55 experimental and 11 control dogs alive on this study. A summary of the major findings in the dogs at death is given in Table 11. We continue to observe the dogs remaining alive at 8.6 to 12.2 yr after exposure.

DESIGN KBQ/KG	A	B	C	D	E	F	G	H	I	J	K	L	MEAN KBQ/KG
21	1215A 30. 5.9 E-2326	1217S 32. 8.1 E-1700	1331A 78. 19. D-1411	1331S 67 24. D-46	1350A 70. 29. E-1909	1340T 33. 12. A-3679	1366C 63. 23. D-1422	1367S 67. 20. E-1580	1379A 120. 26. D-1663	1379T 100. 21. E-1506	1389A 78. 20. D-1352	1380V 110. 27. E-1937	19
10	1220B 14. 5.9 E-3017	1222T 5.6 2.9 E-2773	1334B 4.1 1.3 A-3694	1331U 22. 7.8 E-2496	1350C 22. 8.9 E-1852	1351S 27. 10 E-1925	1366A 23. 5.9 E-2717	1365S 36. 10. E-1947	1378B 31. 7.0 D-739	1377T 37. 10. E-1386	1387B 19. 4.8 E-2294	1390S 24. 7.8 A-3135	7.0
5.2	1217A 9.3 1.9 D-4185	1220T 5.9 2.4 E-2995	1331C 3.4 0.89 D-750	1337T 21. 6.3 A-3687	1336D 22. 6.3 A-3697	1337U 17. 5.9 E-3649	1365A 18. 4.8 E-2307	1364S 22. 4.8 E-1981	1377A 13. 3.7 A-3336	1377S 14. 4.4 D-2218	1387A 8.9 2.5 E-2629	1387S 5.2 1.7 A-3209	3.7
2.6	1215B 4.1 0.89 D-1558	1222S 3.1 2.0 A-4429	1320A 3.4 0.74 E-1934	1324T 14. 2.6 E-3514	1339A 9.6 2.7 A-3686	1338T 3.5 1.4 A-3686	1364A 8.1 2.1 A-3477	1363S 8.1 2.5 A-3477	1376A 5.9 2.7 A-3337	1376T 5.6 2.5 A-3337	1384B 12. 3.5 A-3273	1384S 9.3 3.3 E-2190	2.3
1.1	1220D 1.9 0.85 A-4436	1220S 2.2 0.67 A-4430	1320C 3.0 0.74 E-2273	1320S 3.0 0.78 A-3797	1334D 4.4 2.1 A-3694	1341S 2.3 0.89 A-3679	1362A 4.4 10 A-3478	1362S 2.3 0.63 A-3478	1367B 5.2 1.1 A-3453	1368T 2.6 0.96 D-3102	1384A 5.9 1.6 A-3274	1382S 5.9 1.4 A-3274	1.1
0.37	1221C 0.48 0.20 D-844	1221T 0.85 0.48 A-4422	1335A 1.2 0.35 A-3693	1335T 0.13 0.034 A-3693	1340A 1.8 0.48 A-3687	1340S 0.55 0.21 A-3680	1352C 0.92 0.23 A-3587	1373T 1.9 0.44 A-3339	1374A 1.6 0.52 A-3338	1373U 2.0 0.52 D-2859	1381B 2.9 0.55 A-3272	1381T 2.4 0.55 A-3272	0.37
0.093	1217C 0.19 0.044 A-4437	1223S 0.21 0.078 A-4430	1319B 0.81 0.24 A-3825	1317U 0.074 0.021 E-3575	1342A 0.26 0.078 A-3660	1334S 0.67 0.18 A-3694	1357B 0.41 0.093 A-3552	1357S 0.41 0.13 E-488	1377B 0.74 0.17 A-3316	1378S 0.44 0.11 A-3316	1386A 0.41 0.096 A-3237	1386S 0.33 0.093 A-3237	0.11
0.0085	1214B 0.21 0.035 A-4437	1217T 0.056 0.011 A-4433	1317A 0.052 0.013 E-1832	1319S 0.081 0.023 A-3826	1339B 0.063 0.021 A-3682	1338S 0.031 0.011 A-3682	1355A 0.074 0.015 A-3559	1355T 0.048 0.012 A-3569	1367A 0.063 0.013 E-3199	1368S 0.028 0.0093 A-3464	1381A 0.13 0.022 A-3272	1381S 0.12 0.030 A-3272	0.018
CONTROL	1216B 0 0 D-250	1223T 0 0 A-4415	1318D 0 0 A-3925	1317S 0 0 A-3825	1345A 0 0 A-3653	1342T 0 0 A-3657	1353A 0 0 A-3583	1358S 0 0 A-3549	1368B 0 0 A-3453	1376U 0 0 A-3335	1384B 0 0 A-3234	1380W 0 0 A-3293	0
	1215A 30. 5.9 E-2326	=ANIMAL NUMBER =INITIAL LUNG BURDEN (KBQ) =INITIAL LUNG BURDEN (KBQ/KG) =D=DEAD, E=EUTHANIZED, A=ALIVE - DAYS AFTER EXPOSURE AT DEATH OR ON 9-30-91											

Figure 20. Experimental design for the study of dose-response relationships in immature Beagle dogs that inhaled 1.5 μm AMAD monodisperse $^{239}PuO_2$ (Status as of 9-30-91).

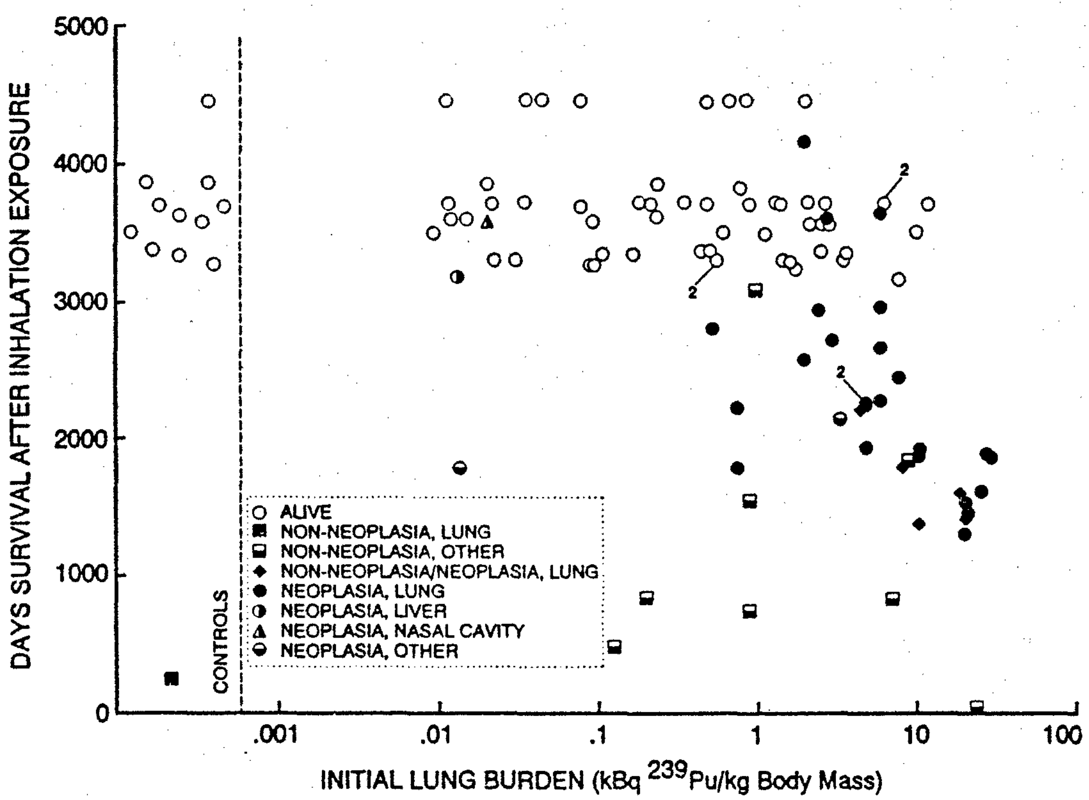

Figure 21. Relationship between initial lung burden of $^{239}PuO_2$ and survival time for immature dogs (Status as of 9-30-91).

Dog 1337U, a female, was euthanized 3649 days after exposure to an ILB of 5.9 kBq per kg body weight. She had an uneventful clinical history until primary lung tumors were diagnosed radiographically 75 days before death. Six weeks before death, anorexia and progressive anemia were noted, and the dog became progressively more debilitated. Euthanasia was recommended.

At necropsy, pulmonary papillary adenocarcinomas were present in the left apical and left diaphragmatic lung lobes. Tumor emboli within the lymphatics and vasculature suggested intrapulmonary metastasis. Other relevant pulmonary lesions included multiple areas of pleural and septal fibrosis and alveolar epithelial hyperplasia with atypia. Lymphoid depletion, fibrosis, and anthracotic pigment were evident in the tracheobronchial lymph node. Incidental necropsy findings included, a benign mixed mammary tumor, nodular adrenal cortical hyperplasia, and focal C-cell hyperplasia of the thyroid.

Dog 1324T, a female, was euthanized 3514 days after exposure to an ILB of 2.6 kBq per kg body weight, because of worsening tachypnea and coughing secondary to a primary lung tumor. The lung tumor was initially diagnosed radiographically 200 days before death. Polycythemia, neutropenia and lymphopenia, and an increased pulmonary interstitial pattern were noted since 42 mo before death.

Necropsy revealed a large adenosquamous pulmonary carcinoma involving the left apical lobe. Extensive lymphatic, vascular, and aerogenous metastases were evident in all lung lobes examined microscopically. Metastases were morphologically that of a papillary adenocarcinoma. Focal metastases to the tracheobronchial lymph nodes were also present. Other incidental findings included a unilateral adrenal cortical adenoma, a benign mammary gland tumor, and multiple hepatic biliary cysts.

Dog 1217A, a male was found dead 4185 days after exposure to an ILB of 1.9 kBq per kg body weight. The dog had only minor clinical problems during its lifetime. At 48 mo of age, an enlarged heart was noted

Table 11

Summary of Major Findings at Death in Dogs that Inhaled Monodisperse 1.5 μm AMAD Particles of $^{239}PuO_2$ when they were Immature (Status as of 9-30-91).

	Number of Dogs	ILB[a] (kBq ^{239}Pu/kg Body Weight)	Survival Times (Days after Exposure)	Cumulative Radiation Dose to Lung (Gy)
<u>^{239}Pu-Exposed</u>				
Non-Neoplasia				
Lung	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	8	0.13-24	46-3102	0.12-8.7
Neoplasia				
Lung Injury with Lung Neoplasia	5	4.4-20	1386-2218	9.4-36
Lung	25[b]	0.021-29	1352-4185	0.05-84
Nasal Epithelium	1[b]	0.021	3570	0.05
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	1	0.013	3199	0.03
Other	2	.013,3.3	1832,2190	.03,6.6
<u>Control</u>				
Non-Neoplasia				
Lung	1	--	250	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	0	--	--	--
Neoplasia	0	--	--	--
Lung Injury with Lung Neoplasia	0	--	--	--
Lung	0	--	--	--
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	0	--	--	--

[a]ILB = Initial lung burden based on whole-body counting of ^{169}Yb.
[b]One dog had nasal carcinoma and lung carcinoma.

radiographically. At 8 years of age, electrocardiograms showed a sinus arrythmia and a slow heart rate. Marked cardiomegaly was noted at that time. The dog appeared clinically stable, but was found dead in the kennel at 11 years of age.

At necropsy, there was marked cardiomegaly and microscopic evidence of biventricular myocardial hypertrophy. Findings of chronic-passive pulmonary congestion supports the diagnosis of congestive heart failure. Lack of valvular or vascular disease and early age of onset is suggestive of primary cardiomyopathy. Two primary lung tumors were found at necropsy. A papillary adenocarcinoma involving the right intermediate lobe and a small fibrosarcoma located subpleurally on the left diaphragmatic lobe. Multiple areas of pulmonary fibrosis, bronchiolar and alveolar epithelial hyperplasia, and chronic nonsuppurative bronchiolitis were also evident. Incidental findings included a unilateral interstitial cell tumor, a small mediastinal thymoma, atrophy of the quadrate lobe of the liver resulting from a remote diaphragmatic hernia and glandular epithelial hyperplasia of the prostate.

Dog 1368T, a female, died under anesthesia during surgical repair of the bilateral inguinal hernias and mammary tumor removal. She had received an ILB of 0.96 kBq per kg body weight 3102 days before death. Numerous transient clinical problems including a grand mal seizure and erythrocytosis were noted during the last year of her life. Bilateral inguinal hernias and a mammary tumor involving L_2 were noted on routine physical exam. The dog died under anesthesia during surgical hernia repair and removal of the mammary gland tumor.

At necropsy, marked systemic congestion and serosanguineous abdominal effusion were present. Definitive gross or microscopic findings pinpointing the proximate cause of death were not evident. However, moderate chronic-passive congestion of the liver and segmental intestinal lymphangiectasis are suggestive of caval obstruction or right heart failure. The immediate cause of death was respiratory arrest followed by cardiovascular collapse. Other findings included a mild lymphocytic thyroiditis, focal nodular hyperplasia of the liver, a unilateral adrenal cortical adenoma, and complex mammary gland adenoma.

Dog 1367A, a male, was euthanized because of a progressive hepatic failure secondary to a primary hepatic tumor 3199 days after receiving an ILB of 0.063 kBq per kg body weight. The dog had several transient clinical findings during its lifetime, including osteomyelitis involving the left foreleg 72 mo before death. An increased pulmonary interstitial pattern was noted on radiographs 36 mo before death. The dog presented 11 days before death with abdominal ascites, severe rear limb edema, and elevated liver enzymes. Euthanasia was recommended.

At necropsy, a primary hepatic fibrosarcoma was found to have infiltrated and replaced extensive portions of liver. A large 4 x 5 x 1.5 cm metastasis was present in the spleen, and lymphatic micrometastasis was evident in the hepatic lymph node. Other notable nonneoplastic findings included simple cystic glandular hyperplasia of the prostate, a mild, chronic, bilateral glomerulonephrosclerosis, and nodular adrenal cortical hyperplasia.

Dog 1317U, a female was euthanized because of an enlarging nasal tumor 3570 days after receiving an ILB of 0.021 kBq per kg body weight. Subclinical anemia and transient polyarthritis were noted at 24 mo of age. An increased pulmonary interstitial pattern and an increased respiration rate were clinically evident 84 mo before death. One month before death, the dog presented for a mucosanguineous nasal discharge and an enlarging bony nasal maxillary mass. Radiographs revealed periosteal new bone formation and ongoing osteolysis. Loss of incisor and canine teeth and progressive difficulty with nosebreathing prompted euthanasia.

At necropsy, a well-differentiated, invasive squamous cell carcinoma infiltrated bilaterally, structures of the nasal cavity, maxillary sinuses, maxilla, and bony palate. Loss of teeth was a result of neoplasia involving periodontal structures of the incisive bones and maxilla. No metastasis was evident. Also significant were two primary papillary adenocarcinomas involving the right apical and left diaphragmatic lung lobes. Morphologically, both tumors were essentially identical; however, lymphatic or vascular metastases were not evident in either case. Alveolar epithelial hyperplasia and pleural and septal fibrosis were present in most lung sections. Other nonneoplastic findings included a unilateral ultimobranchial duct cyst and diffuse C-cell hyperplasia of the thyroid.

f. Repeated Inhalation Exposure of Beagle Dogs to $^{239}PuO_2$. XV.

Study Contact: J. H. Diel

To evaluate the role of chronic exposure to an alpha-emitting aerosol, PuO_2, compared to single acute uptakes of the same radionuclide, adult Beagle dogs inhaled a monodisperse aerosol of $^{239}PuO_2$ (0.75 μm AMAD) either once or once every 6 mo for 10 yr. Twenty-four singly exposed dogs received 3.7 kBq ^{239}Pu; the multiply exposed dogs received either 0.37 or 3.7 kBq per exposure for a maximum of 20 exposures each. There were 24 dogs exposed at the lower dose, and 15 dogs exposed at the upper dose. Nine additional dogs at the upper dose were sacrificed for dosimetry. Twelve control dogs were also given repeated, semiannual sham exposures for the 10-yr duration of the exposures. These dogs are being held for life-span observations. The exposures began in 1977; the final repeated exposures were done in 1987. Specific details of the experimental design considerations, the dose-response models being tested, and the metabolism and dosimetry of the inhaled $^{239}PuO_2$ have been presented in previous annual reports, particularly in LF-58, LMF-91, and LMF-102. Annual summaries for this study have also been included in all other annual reports to the present time.

The current status of this study is shown in the experimental design chart given in Figure 22. Exposure information and dosimetry results are given for each dog in Appendix A. Survival data for dogs in this study are summarized graphically in Figure 23. During this year, four of the dogs that were exposed repeatedly to ^{239}Pu died, as did three control dogs. The major clinical and pathological findings for these animals are summarized below. As of September 30, 1991, there were two singly exposed and four control dogs alive for a total of six animals. A summary of the major findings in these dogs at death is given in Table 12. We continue to observe the surviving dogs, who are between 13 and 14 yr on study.

DESIGN EXPOSR	A	B	C	D	E	F	G	H	I	J	K	L	MEAN KBQ/EXP
SINGLE EXPOSR 3.7KBQ	1028A 5.6 1 E-4072	1040S 3.3 1 D-1651	1036A 3.0 1 E-3671	1050S 5.2 1 D-3564	1050A 4.1 1 A-5143	1055T 6.3 1 E-1558	1058B 5.6 1 E-4348	1062S 6.3 1 E-1010	1060B 4.8 1 E-2715	1077V 7.8 1 E-4097	1063C 4.1 1 D-3901	1073T 22. 1 E-1920	6.7
SINGLE EXPOSR 3.7KBQ	1028B 3.0 1 D-3740	1044U 3.3 1 E-4795	1025A 7.0 1 E-3612	1055W 5.6 1 E-4979	1057B 6.7 1 E-4856	1060S 6.3 1 E-3466	1051B 5.6 1 D-3509	1061T 7.8 1 E-3465	1051A 7.8 1 E-3339	1077S 7.8 1 D-3216	1067B 3.7 1 A-5074	1077U 9.6 1 E-4711	6.3
REPEAT EXPOSR 3.7KBQ	1027C 54. 10 E-2008	1036S 46. 9 E-1623	1040C 47. 9 E-1684	1055U 43. 10 E-1944	1045D 55. 10 D-1908	1049S 45. 8 E-1462	1051D 46. 9 E-1895	1061S 58. 9 E-1631	1062B 75. 10 D-2013	1069S 67. 8 D-1892	1064A 54. 9 E-1829	1070S 49. 10 D-2374	5.6
SACRIF REPEAT EXPOSR 3.7KBQ	1041A 21. 4 S-728	1037T 54. 10 D-1698	1037A 62. 8 E-1530	1049T 10. 2 S-369	1040D 9.3 2 S-364	1049V 57. 7 E-1267	1054D 61. 10 S-1838	1065T 24. 4 S-728	1054C 47. 9 S-1832	1067U 26. 9 S-1749	1064C 15. 2 S-364	1078T 17. 4 S-734	6.3
REPEAT EXPOSR .37KBQ	1025B 8.3 18 E-3713	1029U 8.1 18 E-3571	1035A 7.9 19 E-4372	1046T 3.1 2 D-364	1046B 7.5 16 D-3033	1057S 7.9 18 E-3463	1057A 12 20 E-4143	1067T 11. 20 D-4282	1051A 11. 18 E-3569	1071S 7.9 19 E-4226	1066A 11. 20 D-4294	1078S 8.0 20 E-3624	0.52
REPEAT EXPOSR .37KBQ	1027B 6.0 12 D-2125	1035U 6.8 16 E-4134	1037B 8.9 20 E-3643	1051S 12. 19 E-3517	1041B 8.9 19 E-3377	1057T 8.3 20 D-4446	1054B 9.6 17 E-3205	1055S 13. 19 E-3533	1058C 7.8 20 D-4253	1070U 6.4 14 E-2459	1065B 10. 19 E-3927	1073U 7.6 12 D-1933	0.52
CONTROL	1037E 0 18 E-5080	1044T 0 18 A-5142	1040A 0 13 D-2250	1051T 0 13 D-4208	1043A 0 18 E-3941	1058S 0 18 A-5081	1059A 0 18 A-5115	1066T 0 18 A-5074	1062A 0 6 D-969	1068V 0 18 E-4383	1062C 0 18 D-5050	1077T 0 18 E-4732	0

1028A	=ANIMAL NUMBER
5.6	=TOTAL EXPOSURE TO DATE (KBQ
1	=NUMBER OF EXPOSURE (INCLUDING SHAM EXPOSURES)
E-4072	=A=ALIVE, D=DEAD, E=EUTHANIZED, S=SACRIFICED DAYS AFTER INITIAL EXPOSURE AT DEATH OR ON 9-30-91

Figure 22. Experimental design for the longevity study of Beagle dogs exposed repeatedly by inhalation to 0.75 μm activity median aerodynamic diameter aerosols of $^{239}PuO_2$ (Status as of 9-30-91).

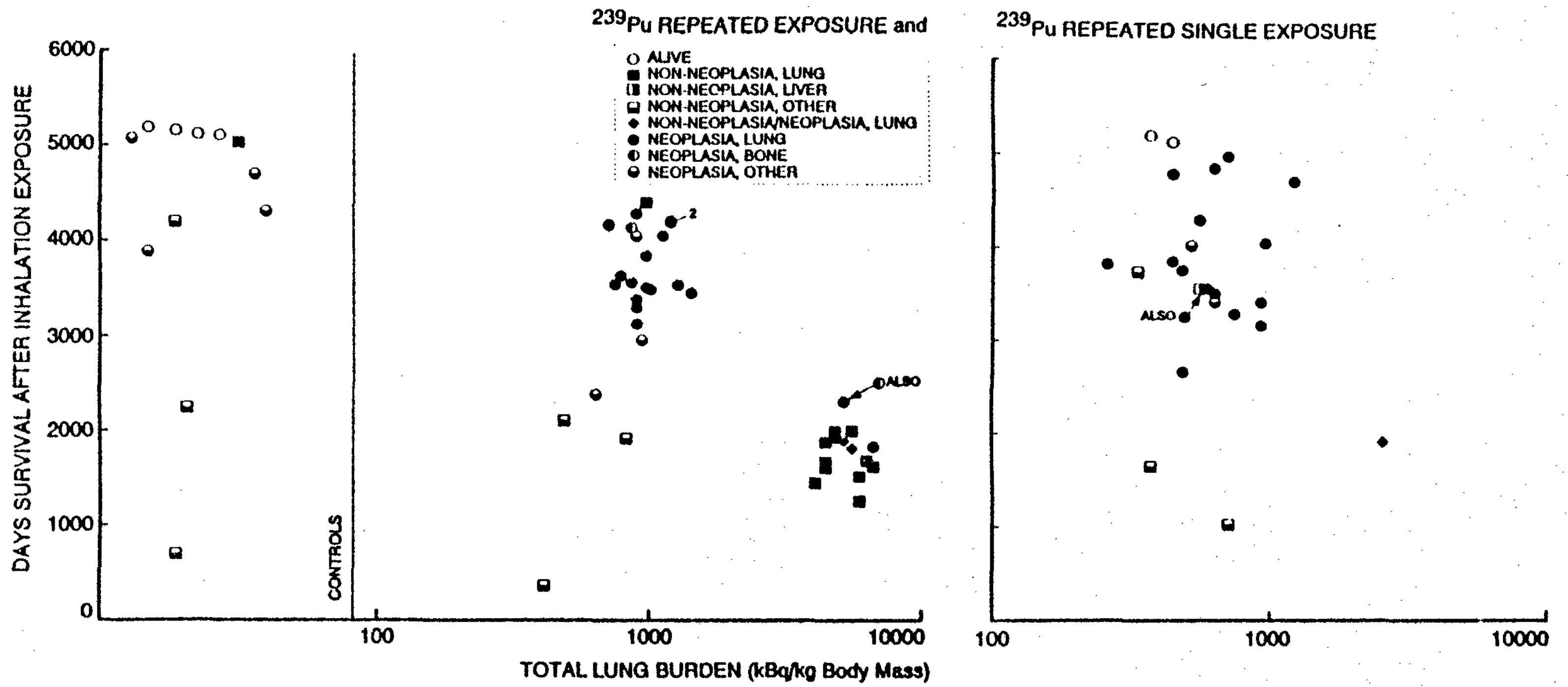

Figure 23. Survival of dogs exposed semiannually by inhalation to monodisperse areosols of $^{239}PuO_2$ (Status as of 9-30-91).

Table 12

Summary of Major Findings at Death in Dogs Repeatedly Exposed by Inhalation to 0.75 μm Aerodynamic Diameter Monodisperse Aerosols of $^{239}PuO_2$ (Status as of 9-30-91).

	Number of Dogs	TLB[a] (kBq ^{239}Pu/kg Body Weight)	Survival Times (Days after Exposure)	Cumulative Radiation Dose to Lung (Gy)
^{239}Pu-Exposed				
Non-Neoplasia				
Lung	12	0.41-0.68	1267-4444	6.1-27
Bone Marrow	0	--	--	--
Liver	1[b]	0.56	3564	4.0
Other	6	0.33-0.81	364-3740	0.73-4.3
Neoplasia				
Lung Injury with Lung Neoplasia	3	0.50-2.6	1829-1920	15-24
Lung	34[b,c]	0.26-1.4	1892-4979	1.9-31
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	2[c]	0.53,0.85	2374,4226	5.4,30
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	5	0.52-0.93	2450-4134	2.8-5.6
ontrol				
Non-Neoplasia				
Lung	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	4	--	969-5050	--
Neoplasia		--	--	--
Lung Injury with Lung Neoplasia	0	--	--	--
Lung	0	--	--	--
Nasal Epithelium	0	--	--	--
TBLN	0	--	--	--
Heart	0	--	--	--
Bone	0	--	--	--
Bone Marrow	0	--	--	--
Liver	0	--	--	--
Other	4	--	3941-5080	--

[a]TLB = Total lung burdens based on whole-body counting of ^{169}Yb.
[b]One dog had a lung tumor and hepatic degeneration.
[c]One dog had lung and bone tumors.

Dog 1077U, a female, was euthanized 4711 days after first exposure to an aerosol of $^{239}PuO_2$ due to the presence of lung tumors. The dog received a total lung burden (TLB) of 1.2 kBq per kg body mass. This dog had a few minor clinical problems during its lifetime. These included an inguinal hernia, an ossifying epulis of the gingiva, spondylosis of T12-13 vertebrae, and poor light reflex in the left pupil. The dog developed tachypnea 6 days prior to death, and radiographs taken 3 days prior to death, suggested the presence of multiple lung tumors.

At necropsy, a papillary, pulmonary adenocarcinoma was in the right apical lung lobe. A papillary adenocarcinoma in the left diaphragmatic lobe was considered a metastasis from the right apical lobe. Multifocal, mild, chronic interstitial pneumonia of the right cardiac lung lobe and severe atrophy and fibrosis of the tracheobronchial and mediastinal lymph nodes were, most likely, treatment-associated lesions. A malignant melanoma of the spindle cell form was in the iris of the left eye.

Dog 1055W, a female, was euthanized with a lung tumor 4979 days after initial exposure. The inhalation exposures resulted in a TLB of 0.70 kBq per kg body mass. Several minor clinical problems were noted during the dog's lifetime. These included bilateral degenerative joint disease of the coxofemoral joints, an increased interstitial lung pattern, vertebral spondylosis, and dental disease. A tumor which was seen in the L_3 mammary gland approximately 17 mo prior to death increased in size. A lung tumor was noted about 7 mo prior to death, progressively grew, and resulted in euthanasia.

At necropsy, a papillary adenocarcinoma was found in the left diaphragmatic lung lobe and had metastasized within the lung to the right apical and right intermediate lobes, and beyond the lung to the tracheobronchial lymph node. A second primary pulmonary neoplasm, a bronchioloalveolar adenoma, was in the right intermediate lung lobe. The L_3 mammary gland contained a complex tubular adenocarcinoma which metastasized to the right diaphragmatic lung lobe. Multifocal, mild, pulmonary interstitial fibrosis with associated alveolar epithelial hyperplasia was considered treatment-related and consistent with radiation pneumonitis. Severe atrophy of the tracheobronchial lymph node was typical of $^{239}PuO_2$ inhalation exposure. A cortical carcinoma was found in the adrenal gland, and an oral malignant melanoma was noted within a focus of chronic proliferative gingivitis.

Dog 1050B, a male, was euthanized because of lung tumors 4856 days after its initial exposure. The dog received a TLB of 0.63 kBq $^{239}PuO_2$ per kg body mass. Clinically, the dog had radiographic evidence of radiation pneumonitis more than 96 mo prior to death. The left testicle was removed because of a Sertoli cell tumor 60 mo before death. Radiographic evidence of a lung mass was first noted more than 24 mo prior to death. Bronchoscopy and bronchoalveolar lavage confirmed the presence of lung tumors 40 days prior to death.

At necropsy, three separate primary carcinomas were found in the lung: a primary, papillary adenocarcinoma of the right apical lung lobe; a primary, adenosquamous carcinoma of the right diaphragmatic lung lobe; and a primary, papillary adenocarcinoma of the apical portion of the left apical-cardiac lung lobe. The left diaphragmatic lung lobe contained a fibrosarcoma which appeared to be a metastasis; the primary fibrosarcoma was not found. Exposure-related lesions included: 1) multifocal, mild, pulmonary, interstitial fibrosis with associated alveolar, epithelial cell hypertrophy and hyperplasia, and occasionally, squamous metaplasia, and 2) severe atrophy of the mediastinal and tracheobronchial lymph nodes. The mild cardiomegaly noted clinically and grossly was considered secondary to pulmonary neoplasia and interstitial fibrosis. A cavernous hemangioma was noted in the retropharyngeal lymph node.

Dog 1044U, a female, was euthanized with a lung tumor 4795 days after the first exposure. The dog received a TLB of 0.44 kBq per kg body mass. Most clinical problems were minor and included dental disease, an interstitial lung pattern, a transverse mandibular fracture, vertebral spondylosis, unilateral medial patellar luxation, and bilateral oronasal fistulas. The terminal illness was associated with a long history of pulmonary neoplasia. A lung tumor was first noted in the cardiac portion of the left apical-cardiac lung lobe approximately 23 mo prior to death. The neoplasm grew progressively. Increased lung sounds, dyspnea, and lethargy resulted in euthanasia.

At necropsy, a papillary adenocarcinoma was found in the left apical-cardiac lung lobe. Additional papillary adenocarcinomas in the right apical lung lobe and the left diaphragmatic lung lobe were considered metastases

from the tumor in the left apical-cardiac lung lobe. Multifocal, mild, alveolar epithelial cell hyperplasia; multifocal, mild, pulmonary, interstitial fibrosis; and severe atrophy of the tracheobronchial lymph node were all considered exposure related.

Dog 1077T, a female control, was euthanized 4765 days after initial exposure to the vector aerosol. Several minor clinical illnesses occurred during its lifetime. These included a grade III/VI heart murmur, right heart enlargement, an increased interstitial pattern in the lungs, and spondylosis of the T_{13}-L_1, $L_{2\text{-}3}$, and L_7-S_1 vertebrae. Mammary neoplasms removed from the R_4 and L_3 mammary glands 8 mo prior to death were a simple tubulopapillary adenocarcinoma and a complex tubular adenocarcinoma, respectively. The simple tubulopapillary carcinoma was present in the lymphatics, vasculature, and inguinal lymph node. Persistent melena appeared 52 days prior to death. The terminal illness was manifested as disorientation, circling in the run, and poor proprioception in the rear limbs.

At necropsy, a carcinoma of the pituitary *pars intermedia* invaded the brain and explained antemortem neurologic signs. Moderate, lymphoplasmacytic gastritis with atrophy may have contributed to intestinal signs such as melena. At least two foci of metastatic mammary adenocarcinoma were found in the lung and were considered metastases from the adenocarcinoma of the R_4 mammary gland. Additional malignant mammary neoplasms present at necropsy were a complex tubular adenocarcinoma of the R_4 mammary gland, a simple papillary adenocarcinoma of the R_5 mammary gland, and a simple tubular adenocarcinoma of the L_4 mammary gland. Moderate focal subpleural fibrosis in the left diaphragmatic lung lobe was associated with moderate alveolar epithelial hypertrophy and hyperplasia and multifocal squamous metaplasia. A few foci of mild interstitial fibrosis were scattered in the lung. These were not treatment-associated lesions, however, as this was a control dog.

Dog 1062C, a male control, was found dead 5050 days after initial exposure to the vector aerosol. Minor clinical problems included bilateral degenerative joint disease of the coxofemoral joints, spondylosis of the T12-L1, L3-4 vertebrae, three episodes of anemia, and three episodes of eosinophilia. The dog had an episode of tachypnea about 105 mo prior to death. Cardiomegaly was first manifested about 96 mo prior to death as right heart enlargement and progressed to generalized cardiomegaly 33 mo prior to death. Clinical signs of cardiac disease were never observed, and the dog was found dead in its run.

At necropsy, the dog had moderate, acute, necrosuppurative, bronchointerstitial pneumonia. The heart was also markedly enlarged, the ventricular myocardium was bilaterally hypertrophied, edema and alveolar histiocytosis were in portions of the lung unaffected by *bronchiolitis obliterans* or acute bronchopneumonia, and marked passive congestion was in the liver. These lesions suggested that the primary disease process was congestive heart failure which predisposed the dog to the development of pneumonia. No valvular lesions were present in the dog. Pulmonary vascular amyloidosis and a solid-follicular thyroid carcinoma, which were present, were potential causes of pulmonary hypertension and hyperthyroidism, both known causes of heart failure. A cortical carcinoma was in the adrenal gland.

Dog 1037E, a male control, was euthanized with a metastatic melanoma 5080 days after initial inhalation exposure to the vector aerosol. Clinically, vertebral spondylosis was present at $T_{10\text{-}11}$, T_{13}-L_6, and L_7-S_1. Ruptured discs were present at T_{13}-L_1, $L_{2\text{-}3}$, and $L_{3\text{-}4}$. A heart murmur was first noted more than 36 mo prior to death and progressed to a grade IV/VI murmur. The thyroid was enlarged 7 mo prior to death, and hypothyroidism was diagnosed 6 1/2 mo prior to death. The terminal illness, an oral malignant melanoma, was first noted approximately 12 mo prior to euthanasia. Despite surgical removal, the tumor recurred, and the dog was euthanized because of pulmonary metastases.

At necropsy, the oral malignant melanoma had recurred locally, and metastases were present in the cervical lymph nodes and lung. The mediastinum contained a thymoma of the predominately epithelial form. An adenoma of the pituitary *pars intermedia* or concomitant disease may have produced hypothyroidism. Thyroid enlargement on the thyroid scan was attributed to multiple simple and multiloculated parathyroid cysts. Moderate endocardiosis of the left atrioventricular valve explained the clinical history of a heart murmur.

3. Annual Report References to Dog Longevity Studies In Which All Dogs Have Died

It is our custom to provide an annual status report on each dog longevity study in which dogs are still alive. These reports provide historical perspective on each study and on the sequence in which different events occurred. When all dogs in a given study are dead, the scientific effort in that study is directed to final histopathological reviews, data analyses, dose-response modeling, and open literature publications.

Recognizing that annual progress reports for an individual study may span about 20 yr, it is desirable to provide the interested reader with a guide to past annual reports and their contents. In the material that follows, a graph that illustrates the relationship between long-term retained radionuclide burden, survival time, and prominent pathological observations at death is presented for each study in which all dogs are dead. This graph is followed by an annotated list of all Annual Report references for that particular study.

a. $^{90}SrCl_2$ Longevity and Sacrifice Studies

Figure 24 provides data on long-term retained burden and survival time for Beagle dogs that inhaled $^{90}SrCl_2$, and Table 13 presents annual report references to these dogs.

b. $^{144}CeCl_3$ Longevity Study

Table 14 presents annual report references to Beagle dogs that inhaled $^{144}CeCl_3$, and Figure 25 provides data on the long-term retained burden and survival time for these dogs.

c. $^{91}YCl_3$ Longevity Study

Figure 26 provides data on the long-term retained burden and survival time on Beagle dogs that inhaled $^{91}YCl_3$, and Table 15 presents annual report references on these dogs.

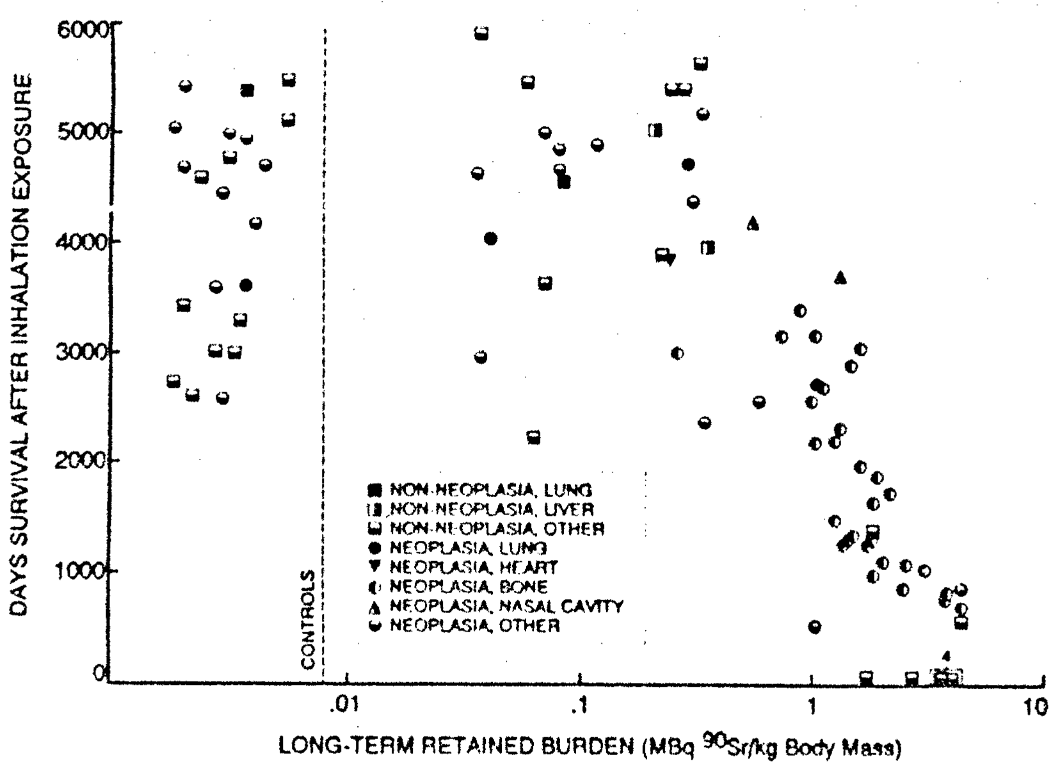

Figure 24. Relationship between long-term retained burden and survival time for Beagle dogs that inhaled $^{90}SrCl_2$.

Table 13

Annual Report References to Longevity and Sacrifice Studies Involving Beagle Dogs that Inhaled $^{90}SrCl_2$

Report No.	Year and Document No.	Pages	Major Contents
I.	1966-67, LF-38	1-18	Exposure details; whole-body retention; ^{85}Sr deposition and fate; dosimetry methodology; early clinical findings, hematology, serum chemistry, microbiology, and pathology in early post-exposure period.
II.	1967-68, LF-39	1-13	Whole-body retention summary; dosimetry; and clinical observations, hematology, and pathology.
III.	1968-69, LF-41	1-7	Whole-body retention; biological effects summary; and survival curves.
IV.	1969-70, LF-43	123-127	Annual status report.
V.	1970-71, LF-44	121-125	Annual status report.
VI.	1971-72, LF-45	129-136	Annual status report, comparison with ^{90}Sr citrate study at the University of Utah.
VII.	1972-73, LF-46	86-90	Annual status report.
VIII.	1973,74, LF-49	89-92	Annual status report.
IX.	1974-75, LF-52	134-138	Annual status report.
X.	1975-76, LF-56	154-157	Annual status report.
XI.	1976-77, LF-58	62-65	Annual status report.
XII.	1977-78, LF-60	68-71	Annual status report.
XIII.	1978-79, LF-69	57-61	Annual status report.
XIV.	1979-80, LMF-84	48-52	Annual status report.
XV.	1980-81, LMF-91	67-72	Annual status report.
XVI.	1981-82, LMF-102	271-275	Final status report.
XVII.	1982-83, LMF-107	183-189	Bone cancer risk estimates.
XVIII.	1983-84, LMF-113	154-158	Study summary.
	1984-85, LMF-114	175-180	Analysis of early hematological effects.
	1984-85, LMF-114	275-279	Logistic analysis of dose-effects data.
	1985-86, LMF-115	167-176	Analysis of late biological effects.
	1988-89, LMF-128	63-65	Effects of route of exposure and dose rate on bone cancers.
	This report	82-84	Alpha- vs. beta-induced bone cancers.

Table 14

Annual Report References to the Longevity Study Involving Beagle Dogs that Inhaled $^{144}CeCl_3$

Report No.	Year and Document No.	Pages	Major Contents
I.	1966-67, LF-38	19-39	Exposure details; whole-body retention; deposition and fate in parallel serial sacrifice study; dosimetry methodology; clinical findings, hematology, clinical chemistry, microbiology, and pathology in early post-exposure period.
II.	1967-68, LF-39	14-25	Deposition and fate in parallel serial sacrifice study; dosimetry; and clinical findings, hematology, and pathology.
III.	1968-69, LF-41	8-14	Whole-body retention, biological effects summary.
IV.	1969-70, LF-43	128-136	Fate and dosimetry, biological effects summary.
V.	1970-71, LF-44	126-135	Whole-body retention, tissue distribution, clinical findings and pathology.
VI.	1971-72, LF-45	137-139	Annual status report.
VII.	1972-73, LF-46	91-95	Dosimetry methodology, annual status report.
VIII.	1973-74, LF-49	93-97	Annual status report.
IX.	1974-75, LF-52	139-142	Annual status report.
X.	1975-76, LF-56	158-163	Annual status report.
XI.	1976-77, LF-58	69-73	Annual status report.
XII.	1977-78, LF-60	76-79	Annual status report.
XIII.	1978-79, LF-69	66-70	Annual status report.
XIV.	1979-80, LMF-84	57-61	Annual status report.
XV.	1980-81, LMF-91	79-83	Annual status report.
XVI.	1981-82, LMF-102	280-283	Annual status report.
XVII.	1982-83, LMF-107	194-197	Annual status report.
XVIII.	1983-84, LMF-113	163-167	Final status report, preliminary cancer risk estimates.
	1984-85, LMF-115	247-250	Nonstochastic effects; nonneoplastic liver disease and tumors in nonirradiated organs.
	1989-90, LMF-130	70-74	Biological effects summary.
	1989-90, LMF-130	75-77	Hepatic tumor comparison.

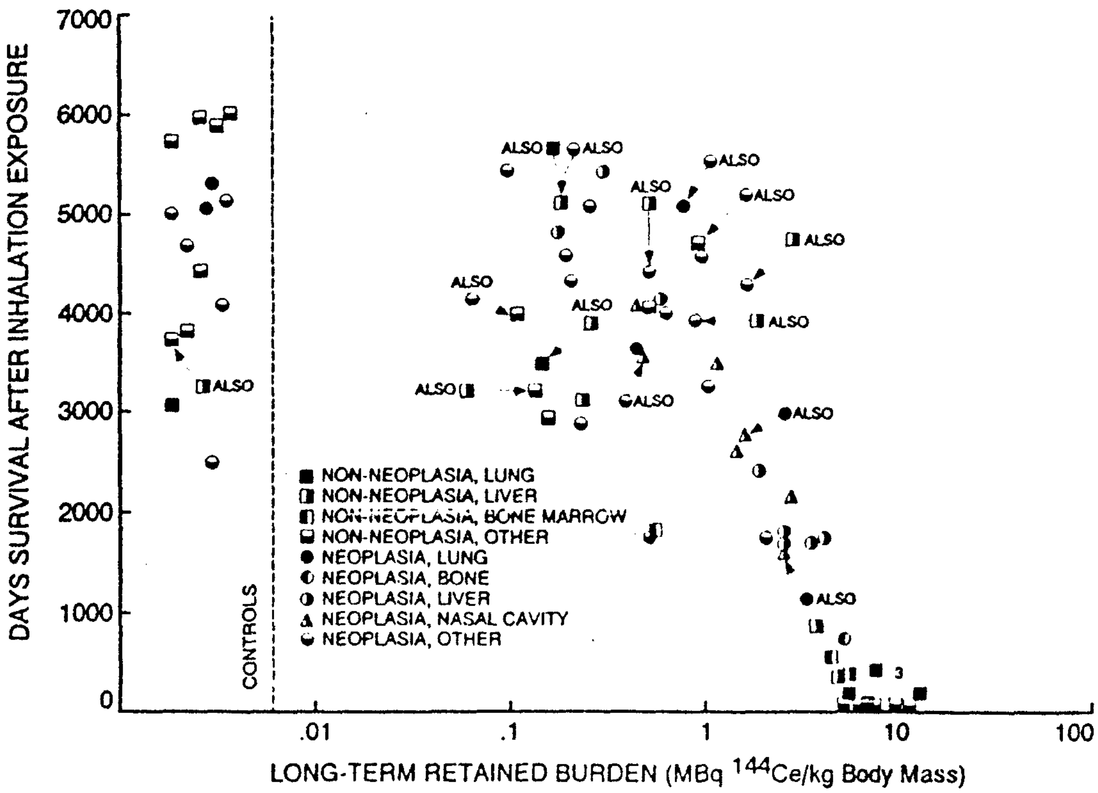

Figure 25. Relationship between long-term retained burden and survival time for Beagle dogs that inhaled $^{144}CeCl_3$.

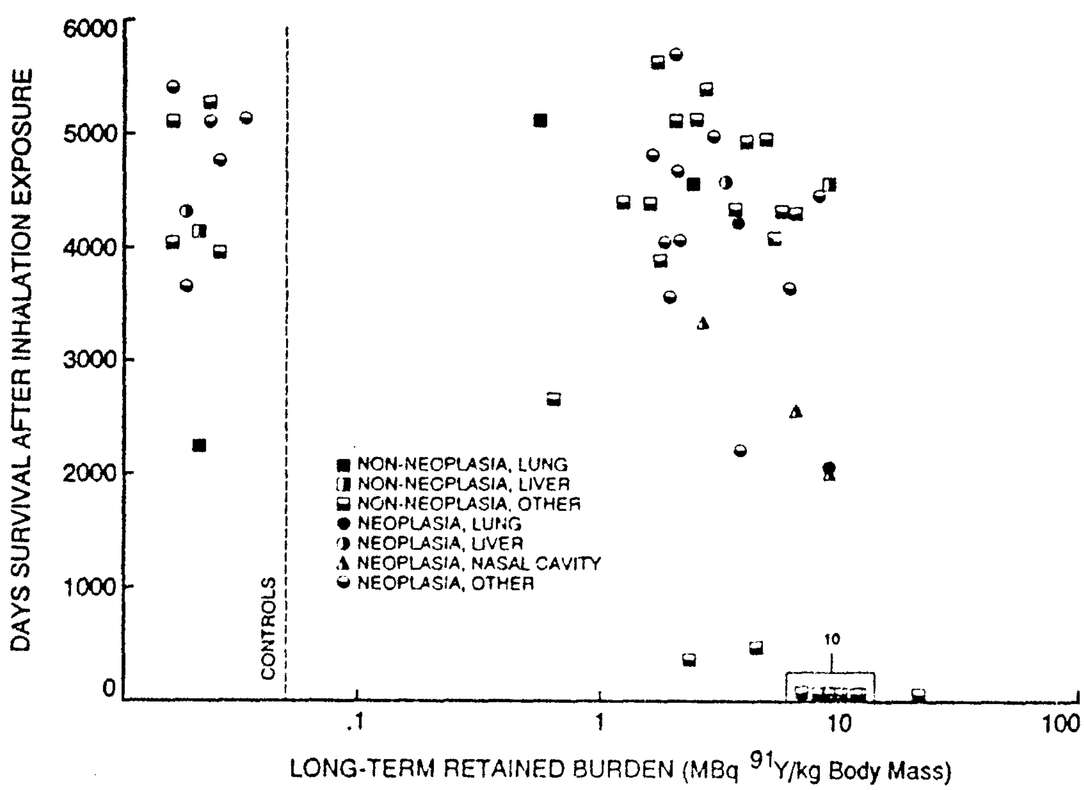

Figure 26. Relationship between long-term retained burden and survival time for Beagle dogs that inhaled $^{91}YCl_3$.

Table 15

Annual Report References to the Longevity Study
Involving Beagle Dogs that Inhaled $^{91}YCl_3$

Report No.	Year and Document No.	Pages	Major Contents
I.	1966-67, LF-38	40-64	Exposure details; whole-body retention; deposition and fate in parallel serial sacrifice study; dosimetry methodology; and clinical observations, hematology, clinical chemistry, microbiology, and pathology in early post-exposure period.
II.	1967-68, LF-39	26-32	Whole-body retention; and clinical observations, hematology, clinical chemistry and pathology.
III.	1968-69, LF-41	15-18	Annual status report.
IV.	1969-70, LF-43	137-139	Annual status report.
V.	1970-71, LF-44	136-138	Annual status report.
VI.	1971-72, LF-45	140-143	Annual status report.
VII.	1972-73, LF-46	96-99	Dosimetry methodology, annual status report.
VIII.	1973-74, LF-49	98-100	Annual status report.
IX.	1974-75, LF-52	143-145	Annual status report.
X.	1975-76, LF-56	164-166	Annual status report.
XI.	1976-77, LF-58	66-68	Annual status report.
XII.	1977-78, LF-60	72-75	Annual status report.
XIII.	1978-79, LF-69	62-65	Annual status report.
XIV.	1979-80, LMF-84	53-56	Annual status report.
XV.	1980-81, LMF-84	73-78	Annual status report.
XVI.	1981-82, LMF-102	276-279	Annual status report.
XVII.	1982-83, LMF-107	190-193	Annual status report.
XVIII.	1983-84, LMF-113	159-162	Final status report, preliminary cancer risk estimates.
	This report	65-67	Biological effects summary.

d. $^{137}CsCl$ Longevity Study

Table 16 presents annual report references to Beagle dogs that were injected with $^{137}CsCl$, and Figure 27 provides data on long-term retained burden and survival time for these dogs.

e. ^{90}Y in Fused Aluminosilicate Particles Longevity Study

Figure 28 provides data on the relationship between ILB and survival time for dogs that inhaled ^{90}Y in fused aluminosilicate particles, and Table 17 presents annual report references to these dogs.

Table 16

Annual Report References to Longevity and Sacrifice Studies Involving Beagle Dogs that were Injected Intravenously with $^{137}CsCl$

Report No.	Year and Document No.	Pages	Major Contents
I.	1967-68, LF-39	54-75	Experimental design; injection details; whole-body retention; urinary and fecal excretion; tissue concentrations; dosimetry details; and early clinical findings, hematology, serum chemistry, and pathology in early post-exposure period.
II.	1968-69, LF-41	36-45	Whole-body retention; dosimetry; microbiology; immunology; hematology; and clinical findings, biochemistry, and pathology.
III.	1969-70, LF-43	140-145	Dosimetry, biological effects summary.
IV.	1970-71, LF-44	139-144	Whole-body retention, biological effects summary.
V.	1971-72, LF-45	144-146	Annual status report.
VI.	1972-73, LF-46	100-102	Annual status report.
VII.	1973-74, LF-49	101-103	Annual status report.
VIII.	1974-75, LF-52	146-149	Annual status report.
IX.	1975-76, LF-56	167-171	Annual status report.
X.	1976-77, LF-58	74-77	Annual status report.
XI.	1977-78, LF-60	80-83	Annual status report.
XII.	1978-79, LF-69	71-74	Annual status report.
XIII.	1979-80, LMF-84	62-66	Annual status report.
XIV.	1980-81, LMF-91	84-89	Annual status report.
XV.	1981-82, LMF-102	284-288	Annual status report.
XVI.	1982-83, LMF-107	198-202	Annual status report.
XVII.	1983-84, LMF-113	168-171	Annual status report.
XVIII.	1984-85, LMF-114	181-184	Final status report.
	1989-90, LMF-130	66-69	Biological effects summary.

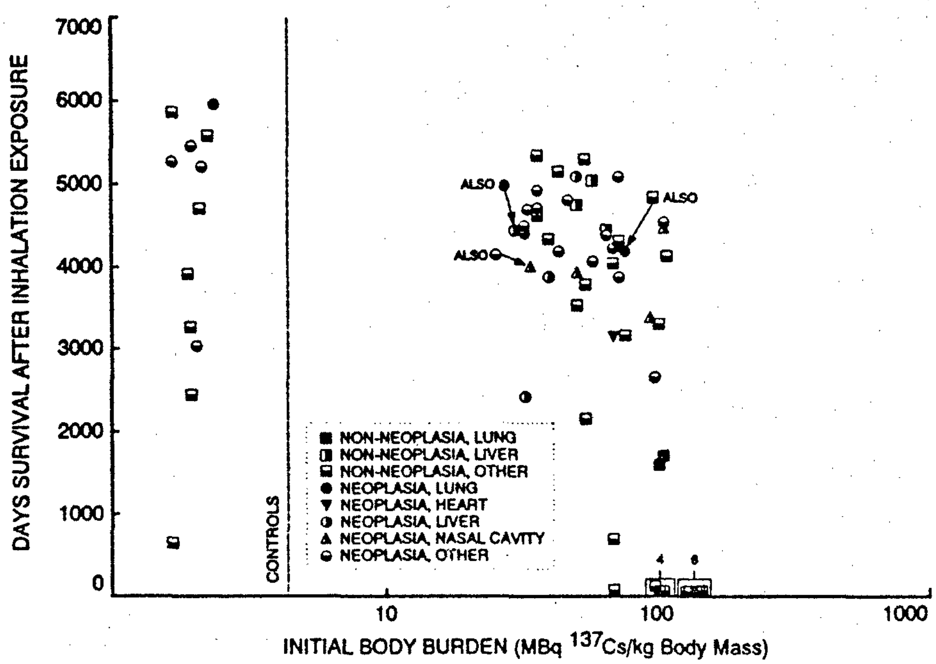

Figure 27. Relationship between long-term retained burden and survival time for dogs that were injected intravenously with $^{137}CsCl$.

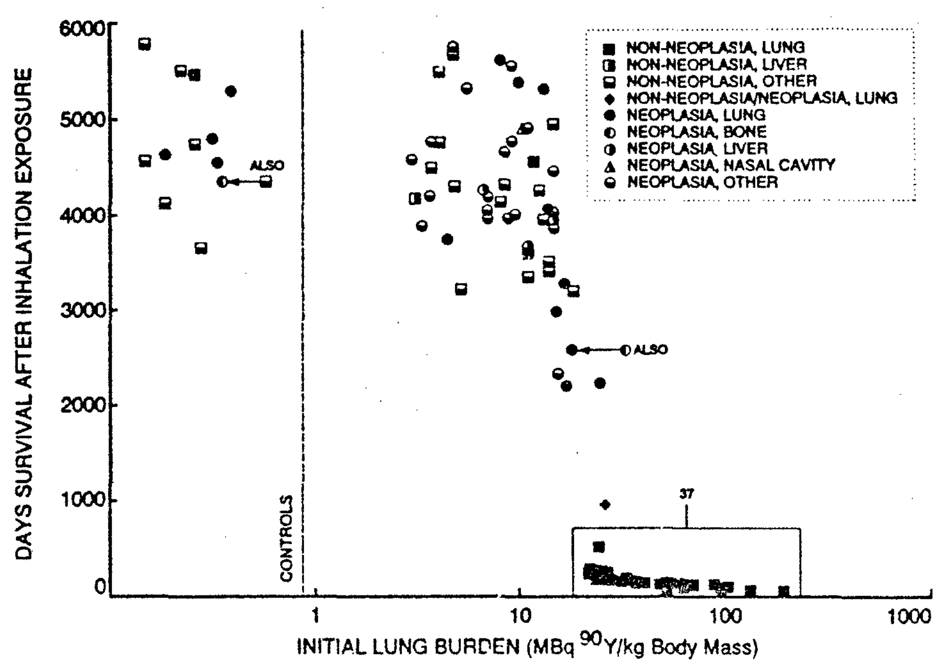

Figure 28. Relationship between ILB of ^{90}Y and survival time for dogs that inhaled ^{90}Y in fused aluminosilicate particles.

Table 17

Annual Report References to Longevity and Sacrifice Series
Involving Beagle Dogs that Inhaled ^{90}Y in Fused Aluminosilicate Particles

Report No.	Year and Document No.	Pages	Major Contents
I.	1968-69, LF-41	46-58	Experimental procedures; whole-body retention; excretion; tissue distribution; dosimetry; and clinical observations, hematology, pulmonary function, clinical chemistry, and pathology.
II.	1969-70, LF-43	146-162	Experimental procedures; experimental design (8 blocks); tissue distribution; and clinical observations, microbiology, and pathology.
III.	1970-71, LF-44	145-150	Full experimental design, dosimetry summary, and biological effects summary.
IV.	1971-72, LF-45	147-150	Annual status report.
V.	1972-73, LF-46	103-107	Annual status report.
VI.	1973-74, LF-49	104-107	Annual status report.
VII.	1974-75, LF-52	150-153	Annual status report.
VIII.	1975-76, LF-56	172-175	Annual status report.
IX.	1976-77, LF-58	78-82	Annual status report.
X.	1977-78, LF-60	84-88	Annual status report.
XI.	1978-79, LF-69	75-78	Annual status report.
XII.	1979-80, LMF-84	67-70	Annual status report.
XIII.	1980-81, LMF-91	90-95	Annual status report.
XIV.	1981-82, LMF-102	289-294	Annual status report.
XV.	1982-83, LMF-107	203-207	Annual status report.
XVI.	1983-84, LMF-113	172-176	Annual status report.
XVII.	1984-85, LMF-114	185-190	Annual status report.
XVIII.	1985-86, LMF-115	177-181	Annual status report.
XIX.	1986-87, LMF-120	205-208	Final status report.
	1986-87, LMF-120	196-204	Preliminary lung cancer risk estimates.
	1989-90, LMF-130	78-81	Beta dose-rate effects in lung.

f. ^{91}Y in Fused Aluminosilicate Particles Longevity Study

Table 18 presents annual report references to Beagle dogs that inhaled ^{91}Y in fused aluminosilicate particles, and Figure 29 provides data on the long-term burden and survival time of these dogs.

Table 18

Annual Report References to Longevity and Sacrifice Series Involving Beagle Dogs that Inhaled ^{91}Y in Fused Aluminosilicate Particles

Report No.	Year and Document No.	Pages	Major Contents
I.	1969-70, LF-43	163-182	Exposure details; whole-body retention; deposition and fate in parallel serial sacrifice study; excretion in urine and feces; dosimetry methodology; experimental design (4 blocks); and clinical observations, hematology, pulmonary physiology, clinical chemistry, and pathology in early post-exposure period.
II.	1970-71, LF-44	151-163	Full experimental design; initial deposition; whole-body retention; tissue distribution; dosimetry; and clinical observations; hematology, clinical chemistry, pulmonary function, and pathology for early post-exposure period.
III.	1971-72, LF-45	151-156	Biological effects summary.
IV.	1972-73, LF-46	108-111	Annual status report.
V.	1973-74, LF-49	108-112	Annual status report.
VI.	1974-75, LF-52	154-159	Annual status report.
VII.	1975-76, LF-56	176-179	Annual status report.
VIII.	1976-77, LF-58	83-86	Annual status report.
IX.	1977-78, LF-60	89-93	Annual status report.
X.	1978-79, LF-69	79-82	Annual status report.
XI.	1979-80, LMF-84	71-75	Annual status report.
XII.	1980-81, LMF-91	96-100	Annual status report.
XIII.	1981-82, LMF-102	295-299	Annual status report.
XIV.	1982-83, LMF-107	208-212	Annual status report.
XV.	1983-84, LMF-113	177-181	Annual status report.
XVI.	1984-85, LMF-114	191-195	Annual status report.
XVII.	1985-86, LMF-115	182-186	Annual status report.
XVIII.	1986-87, LMF-120	209-212	Final status report.
	1986-87, LMF-120	196-204	Preliminary lung cancer risk estimates.
	1989-90, LMF-130	78-81	Beta dose-rate effects in lung.
	This report	61-64	Biological effects summary.
	This report	79-82	Alpha- vs. beta-induced lung cancer.

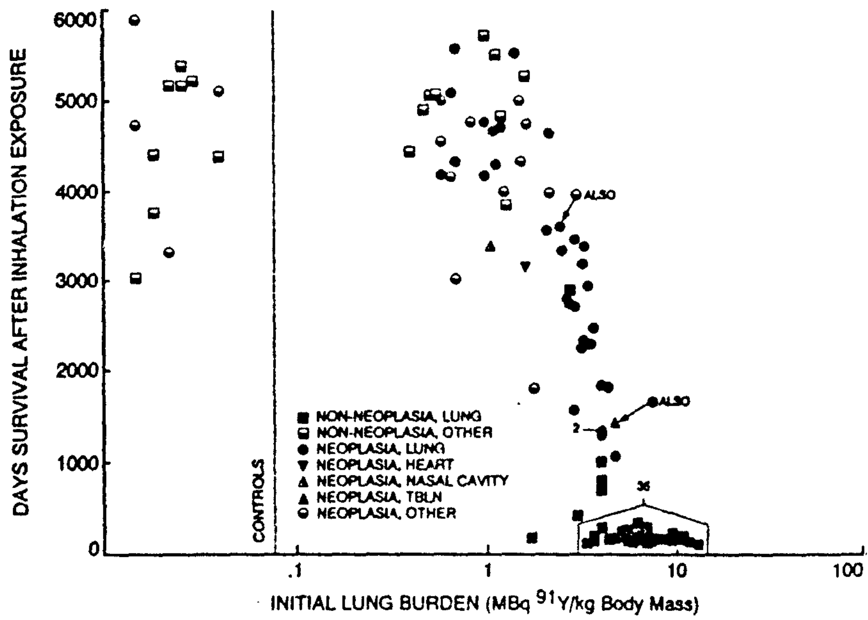

Figure 29. Relationship between ILB of ^{91}Y and survival time for dogs that inhaled ^{91}Y in fused aluminosilicate particles.

g. ^{144}Ce in Fused Aluminosilicate Particles Longevity Study

Figure 30 provides data on the long-term burden and survival time for Beagle dogs that inhaled ^{144}Ce in fused aluminosilicate particles, and Table 19 presents annual report references to these dogs.

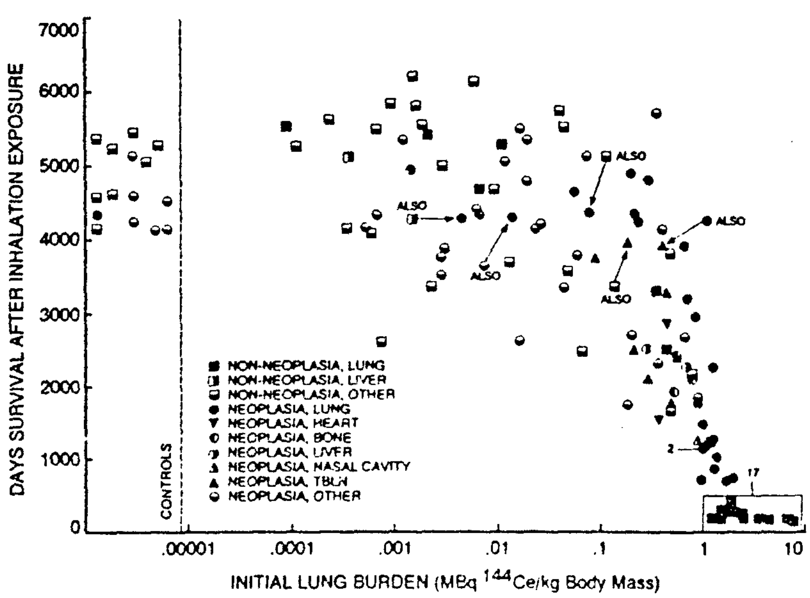

Figure 30. Relationship between ILB of ^{144}Ce and survival time for dogs that inhaled ^{144}Ce in fused aluminosilicate particles.

Table 19

Annual Report References to Longevity and Sacrifice Series Involving Beagle Dogs that Inhaled ^{144}Ce in Fused Aluminosilicate Particles

Report No.	Year and Document No.	Pages	Major Contents
I.	1967-68, LF-39	33-53	Exposure details; whole-body retention; deposition and fate in parallel serial sacrifice study and dogs dying in early post-exposure period; and clinical observations, hematology, pulmonary physiology, clinical chemistry, and pathology in early post-exposure period.
II.	1968-69, LF-41	19-35	Partial experimental design; whole-body retention; tissue distribution and retention; dosimetry; and clinical observations, pulmonary function, clinical chemistry, hematology, immunology and pathology.
III.	1969-70, LF-43	183-187	Metabolism and dosimetry; and biological effects summary.
IV.	1970-71, LF-44	164-180	Full experimental designs for Series I and II; tissue distribution and retention; clinical observations; and pathology.
V.	1971-72, LF-45	157-166	Annual status report.
VI.	1972-73, LF-46	112-115	Annual status report.
VII.	1973-74, LF-49	113-117	Annual status report.
VIII.	1974-75, LF-52	160-164	Annual status report.
IX.	1975-76, LF-56	180-185	Annual status report.
X.	1976-77, LF-58	87-92	Annual status report.
XI.	1977-78, LF-60	94-98	Annual status report.
XII.	1978-79, LF-69	83-91	Annual status report.
XIII.	1979-80, LMF-84	76-81	Annual status report.
XIV.	1980-81, LMF-91	101-108	Annual status report.
XV.	1981-82, LMF-102	300-305	Annual status report.
XVI.	1982-83, LMF-107	213-219	Annual status report.
XVII.	1983-84, LMF-113	182-187	Annual status report.
XVIII.	1984-85, LMF-114	196-201	Annual status report.
XIX.	1985-86, LMF-115	187-192	Annual status report.
XX.	1986-87, LMF-120	213-216	Annual status report.
	1986-87, LMF-120	196-204	Preliminary lung cancer risks.
XXI.	1987-88, LMF-121	157-163	Final status report.
	1988-89, LMF-128	66-68	Age-related early health effects.
	1988-90, LMF-130	78-81	Beta dose-rate effects in lung.
	This report	75-78	Interspecies lung cancer risks.
	This report	79-82	Alpha- vs. beta-induced lung cancer.

h. ^{144}Ce in Fused Aluminosilicate Particles, Aged-Dog Longevity Study

Table 20 presents annual report references to aged Beagle dogs that inhaled ^{144}Ce in fused aluminosilicate particles, and Figure 31 presents data on the ILB and survival time of these dogs.

i. $^{239}PuO_2$ Aged-Dog Longevity Study

Figure 32 provides data on the ILB and survival time of aged Beagle dogs that inhaled $^{239}PuO_2$, and Table 21 presents annual report references to these dogs.

Table 20

Annual Report References to the Longevity Study Involving Aged Beagle Dogs that Inhaled ^{144}Ce in Fused Aluminosilicate Particles

Report No.	Year and Document No.	Pages	Major Contents
I.	1971-72, LF-45	172-176	Experimental design (6 blocks); exposure details; dosimetry; and early biological results.
II.	1972-73, LF-46	122-127	Comparison of tissue distribution and biological effects with those in young-adult dogs; summary of early biological results; and annual status report.
III.	1973-74, LF-49	122-125	Annual status report.
IV.	1974-75, LF-52	169-172	Complete experimental design, annual status report.
V.	1975-76, LF-56	190-194	Annual status report.
VI.	1976-77, LF-58	97-101	Annual status report.
VII.	1977-78, LF-60	94-98	Annual status report.
VIII.	1978-79, LF-69	96-100	Annual status report.
IX.	1979-80, LMF-84	86-89	Annual status report.
X.	1980-81, LMF-91	113-116	Annual status report.
XI.	1981-82, LMF-102	310-313	Annual status report.
XII.	1982-83, LMF-107	224-227	Final status report.
XIII.	1983-84, LMF-113	193-195	Study summary.
	1988-89, LMF-128	66-68	Age-related early health effects.

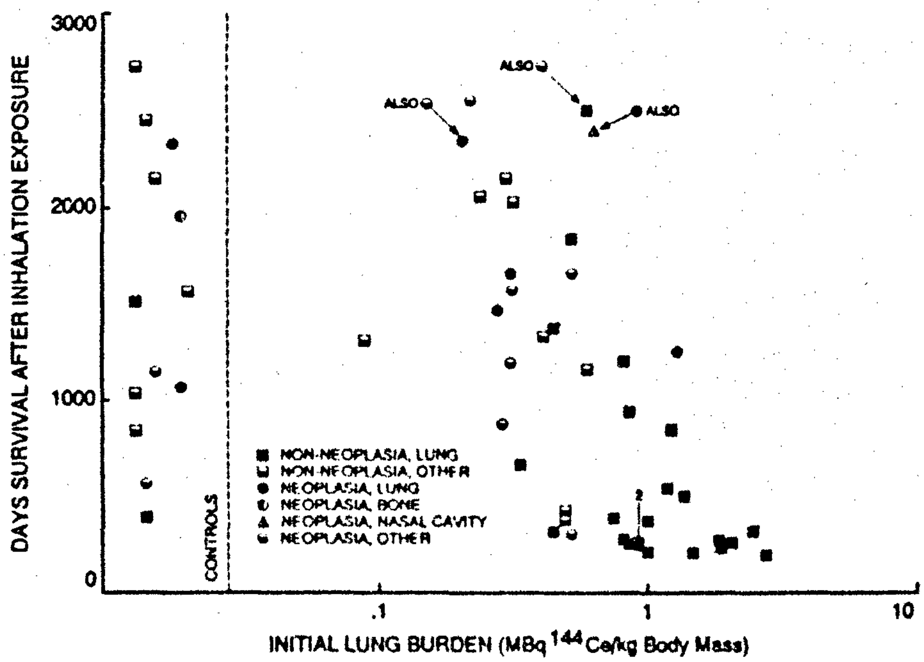

Figure 31. Relationship between ILB of ^{144}Ce and survival time for aged dogs that inhaled ^{144}Ce in fused aluminosilicate particles.

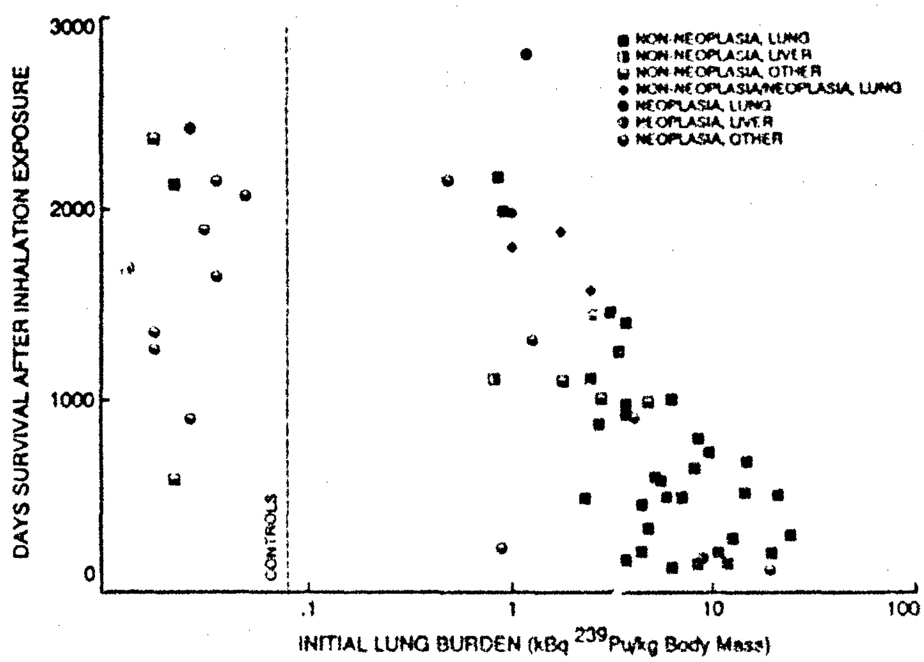

Figure 32. Relationship between ILB of ^{239}Pu and survival time for aged dogs that inhaled $^{239}PuO_2$.

Table 21

Annual Report References to the Longevity Study Involving Aged Beagle Dogs that Inhaled $^{239}PuO_2$

Report No.	Year and Document No.	Pages	Major Contents
I.	1978-79, LF-45	141-144	Experimental design; initial lung burdens.
II.	1979-80, LMF-84	143-145	Current entries into study, early biological effects.
III.	1980-81, LMF-91	169-173	Annual status report.
IV.	1981-82, LMF-102	347-351	Full experimental design, annual status report.
V.	1982-83, LMF-107	264-268	Annual status report.
VI.	1983-84, LMF-113	237-241	Annual status report.
VII.	1984-85, LMF-114	249-253	Annual status report.
VIII.	1985-86, LMF-115	239-242	Annual status report.
IX.	1986-87, LMF-120	266-270	Annual status report.
X.	1987-88, LMF-121	157-163	Final status report.

D. COMPLETION ACTIVITIES FOR THE ITRI STUDIES

1. Completion of Individual Studies

At the present time, there are 13 ITRI studies in which all dogs have died. These are the studies receiving most of the current efforts directed to study completions. The general strategy being followed for each study is shown in Table 22.

Table 22

General Strategy for Completion of Individual Life-Span Studies in Dogs at ITRI

- Collect and organize materials and data
- Conduct detailed reviews
  - Dosimetry
  - Clinical
  - Pathology
- Analyze results
- Publish basic manuscripts
  - Dosimetry
  - Biological effects
  - Dose-Response modeling
- Prepare cross-cutting risk analyses and manuscripts
  - Among ITRI dog studies
  - Across species including humans
  - With other laboratories
- Send materials to National Radiobiology Archives

A review of the dosimetry, clinical and pathology materials and records for each dog is necessary to assure uniformity in thoroughness of examination and terminology. Because each life-span study spanned nearly 2 decades, numerous veterinary clinicians and pathologists have been involved. Over such a span of time, individuals, concepts, treatments, terminology, and completeness of diagnosis have changed. Part of the purpose of these reviews is to establish standard terminology, diagnostic criteria, and reporting format. The general approach is for a team comprised of one pathologist, one clinician, and a radiation biologist to review a complete study together. Each individual reviews the appropriate material for their specialty, and then all team members agree together on the diagnoses and other findings. The information is then organized on forms and entered into the database.

In the dosimetry portion of this effort, the radiation biologist reviews the performance of the counting equipment, consistency of the standards, and the retention functions for the radionuclide of interest in the various organs of concern. This ensures that the dosimetry is consistent over a study and that changes in counting efficiencies and standards did not affect the results of these long studies. It also ensures that the methods for dose calculations are consistent within each experiment. The dosimetry information is then entered into the dosimetry database.

The clinical materials being reviewed are the medical records, radiographs, hematology data, and clinical chemistry data. The pathologist reviews the written gross necropsy report, biopsy reports, and histopathology and final pathology reports for completeness; reviews the slides for tumors, and determines the organs of major concern; and reviews any photographs of the organs taken at gross necropsy.

The clinician and the pathologist discuss each case to establish the following diagnoses: 1) immediate cause of death, 2) primary cause of death, 3) major contributing diseases, and 4) incidental diseases and findings. Under each category, sufficient supporting information is given to demonstrate the basis for the diagnosis. This information is then coded into SNODOG (a modified version of SNOMED) and entered into the database.

Table 23 gives the current priority ranking for completion of these study reviews through the end of FY-1993. Through the end of FY-1991, clinical and pathologic reviews of materials and records have been completed on five studies - $^{90}SrCl_2$, $^{144}CeCl_3$, $^{137}CsCl$, $^{238}PuO_2$ (1.5 μm) and $^{238}PuO_2$ (3.0 μm). It is anticipated that the study of $^{91}YCl_3$ will be completed in early FY-1992. Completion of reviews for these six studies is an important point in time because these six studies contain the most soluble radionuclide forms in the ITRI program. Therefore, the broadest range of organs is a risk in these studies. Effort will also be devoted to establishing a relatively large database on combined control dogs, both for use within the ITRI program and more broadly across laboratories through the National Radiobiology Archives. Emphasis in FY-1993 will be directed to studies of relatively insoluble forms on beta-emitting radionuclides.

Table 23

Current Priority Order and Schedule for Completing Reviews of Individual Dog Life-Span Studies at ITRI

Fiscal Year	Dog Life-Span Study
1990	$^{90}SrCl_2$
	$^{144}CeCl_3$
	$^{137}CsCl$
1991	$^{238}PuO_2$ (1.5 μm)
	$^{238}PuO_2$ (3.0 μm)
1992	$^{91}YCl_3$
	Control Dogs
1993	^{90}Y-FAP
	^{91}Y-FAP
	^{144}Ce-FAP
	^{90}Sr-FAP

Because of the maturity of the entire series of dog life-span studies at ITRI, most of the living dogs on study are also approaching the end of their life spans. Table 24 lists the number of dogs alive in each of the eight studies containing living dogs and the projected year in which the last dog is expected to die. These studies will continue with the daily observation of the dogs, pathological examination of each animal when it dies, and the collection of excreta and tissues for radiochemical analysis for dosimetry. Each study will be integrated into the wrap-up schedule based on the projected date of death of all of the animals. In addition, samples of all tumors of sufficient size are being collected and preserved at -70°C for use in other projects. These samples provide valuable material for evaluating oncogenes and gene activation products present in radiation-induced tumors. Material is also available for *in situ* hybridization and immunohistochemistry studies.

Table 24

Projected Dates for All Dogs to Have Died on the Ongoing Life-Span Radionuclide Toxicity Studies

Radionuclide and Form	Completion of Inhalation Exposure	Number of Dogs Alive 9-30-91	Projected Year of Last Death
^{144}Ce-FAP (Immature)	1972-1976	1	1992
$^{239}PuO_2$ (Repeated Exposures)	1977-1988	6	1993
$^{239}PuO_2$ (0.75 μm)	1977-1979	4	1995
$^{239}PuO_2$ (1.5 μm)	1977-1979	21	1995
$^{239}PuO_2$ (3.0 μm)	1977-1979	8	1995
$^{239}PuO_2$ (Immature)	1977-1982	66	1998

2. Databases

Over the past 30 yr, a number of different database approaches have been used at ITRI for the purpose of managing the storage and retrieval of the data and records produced in different segments of the life-span studies program. These databases have involved a broad range of information on topics such as breeding, inoculation, clinical observations, clinical pathology results, necropsy reports, pathologic diagnoses, radionuclide counting data, and analytical radiochemistry results. Some of the previous databases used have been written in-house, and others were obtained from commercial sources. A long-standing problem has been the difficulty of retrieving and using data from several sources at the same time. Also, because of these database differences, the results were not in appropriate formats for eventual transfer to the National Radiobiology Archives (NRA).

A concerted effort is continuing to re-establish these major databases within a common software framework. The FOCUS database software is being used for this purpose. Highest priority was given first to the development of a health effects database for use in the final review of all clinical and pathologic materials for each dog. Basic details of this database were given in the 1988-1989 annual report (LMF-128, pp. 84-85). During the past year, minor changes were incorporated to improve its usefulness. This database is now an important tool in our health effects evaluation process. Other databases that have been set up in a FOCUS format include the colony management database, the clinical pathology database, the radionuclide counting database, and the analytical chemistry database. Additional testing and modifications of these systems will be required before they reach the same point of maturity as the health effects database.

3. Collaborations with Other Investigators

Two interlaboratory collaborations were actively pursued during the past fiscal year. One of these involved collaboration between investigators at the University of California at Davis, University of Utah, and ITRI to study the similarities and differences among bone tumor types and occurrences in dogs given ^{90}Sr by different routes of administration. These comparisons were completed and submitted for publication in the *International Journal of Radiation Biology* in FY-1991.

A second developing collaboration relates to the life-span studies of dogs injected with $^{137}CsCl$ at either Argonne National Laboratory (ANL) or at ITRI. All dogs in both studies are dead. It was proposed that ITRI investigators conduct detailed biomedical reviews of the materials and records from the ANL study in a manner similar to that used recently for the ITRI study involving $^{137}CsCl$. Meetings were held between the ANL and ITRI investigators, and the study materials were assembled for shipping. It is expected that the transfer of these materials from ANL to ITRI will occur soon. When these evaluations and analyses are completed, the ANL materials will be sent to the NRA for archiving.

A third area of collaboration that should develop in FY-1992 relates to interlaboratory reviews and analyses on control dog information and the establishment of centralized databases on control dog information at the NRA.

4. Third International Workshop on Respiratory Tract Dosimetry

In July 1990, ITRI, along with parts of DOE and CEC, co-sponsored a workshop on the dosimetry of inhaled radioactive materials in the respiratory tract. This workshop, which was attended by 86 scientists and health protection specialists, 22 from eight other countries, provided an opportunity to exchange and discuss various information needs and sources. Data from ITRI studies were important inputs to the success of this workshop. The proceedings of this workshop were published in *Radiation Protection Dosimetry 38*:1-249, 1991.

E. RECENT RESEARCH ACCOMPLISHMENTS

1. Biological Effects of ^{91}Y in Relatively Insoluble Particles Inhaled by Beagle Dogs

F. F. Hahn, W. C. Griffith, C. H. Hobbs, B. A. Muggenburg, and B. B. Boecker

The toxicity of ^{91}Y inhaled in relatively insoluble particles is being investigated as part of the ITRI program to evaluate the biological effects of inhaled beta-emitting radionuclides. A group of 108 dogs was observed over their life span for the biological effects of inhaled ^{91}Y. Equal numbers of male and female dogs, born and raised in the ITRI colony, were given single, brief, nose-only exposures to aerosols of fused aluminosilicate particles containing ^{91}Y to achieve graded ILB of radioactivity. These techniques have been previously described (McClellan, R. O. *et al.* In *Life-Span Radiation Effect Studies in Animals. What Can They Tell Us?* [R. C. Thompson and J. A. Mahaffey, eds.], Office of Scientific and Technical Information, U. S. Department of Energy, Oak Ridge, TN, p. 74, 1986). Another group of 30 dogs was exposed to ^{91}Y aerosols in the same manner and serially sacrificed for distribution data over the first 320 days after exposure. Whole-body counting of each dog was used to determine the ILB. Mean organ absorbed dose rates and cumulative doses were calculated for each life-span dog using its own whole-body retention data and the relationship between lung burden and total burden determined in the parallel serial sacrifice study.

Each dog was given a medical evaluation annually and observed daily until death occurred spontaneously, or the dog was euthanized in a moribund condition. Complete gross and histopathologic examinations were made at death and included routine observation of all organ systems and notation of all lesions. Lifetime risks for malignant tumors of the lung were estimated using a proportional hazards model. This model is based on the age-specific incidence of tumors and estimates relative risk as the ratio of changes in the age-specific incidence as a function of the radiation dose to lung. The proportional hazards model in this report used nonparametric estimates of the baseline hazard and additive linear functions of the radiation dose for relative risks, similar to the methods used in the BEIR V report (NAS/NRC, Committee on the Biological Effects of Ionizing Radiation. *Health Effects of Exposure to Low Levels of Ionizing Radiation*, BEIR V, National Academy Press, Washington, DC, 1990).

The size distribution of the aerosol particles as determined by cascade impactor analysis was approximately lognormal. Activity mean aerodynamic diameters ranged from 1.5 to 2.3 μm with geometric standard deviations between 1.6 and 2.0. Real diameters ranged from 1.0 to 1.5 μm. ILBs achieved for the 96 dogs that inhaled ^{91}Y ranged from 0.41 to 13 MBq/kg body weight.

The average retention of ^{91}Y in the body was expressed by a two-component exponential function: $B(t) = 0.54e^{-3.88t} + 0.46e^{-0.0132t}$. Tissue distribution data showed that by 4 days after inhalation exposure, almost all of the ^{91}Y retained was in the lung; as time progressed, the relative amount in the lung decreased slowly. The retention of ^{91}Y in the lungs was a linear function with an effective half-life (radioactive decay plus translocation) of about 50 days.

Tissue concentrations of ^{91}Y in other organs showed that only the TBLN, bone and liver had significant activities. The concentration of ^{91}Y in the TBLN equaled that of the lung by 50 days after exposure and continued to increase beyond that time. Concentrations of ^{91}Y in the liver and skeleton were about two orders of magnitude less than those of the lung and TBLN.

Figure 33 illustrates the cumulative doses to the lung, liver, and skeleton that would be expected from ^{91}Y in aluminosilicate particles deposited in the lung based on the results of the serial sacrifice study results. Survival of the dogs as related to ILB and the principal lesions at death are shown in Figure 34. Forty-one dogs, with radiation doses to lung ranging from 8.0 to 600 Gy, died of pulmonary vasculitis, radiation pneumonitis, and/or pulmonary fibrosis at 113 to 2890 days after exposure. Most of these dogs (37) died before 500 days after exposure with relatively high radiation doses (> 250 Gy) and with lesions clearly related to radiation injury. At later times, pulmonary neoplasia was a frequent finding, occurring in 32 dogs. The earliest death from pulmonary neoplasia was 1115 days after exposure. All lung tumors were epithelial in nature and originated in the alveoli

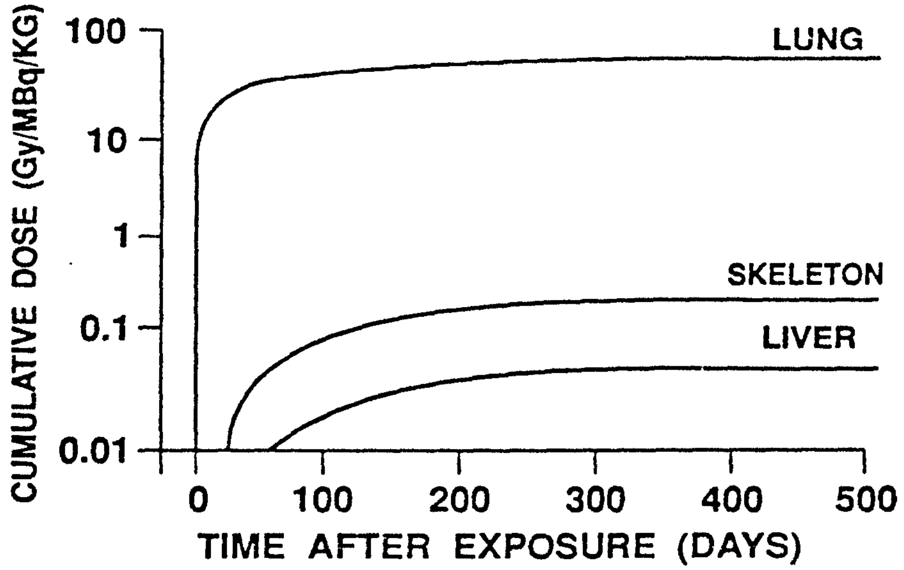

Figure 33. Dose to lung, skeleton, and liver in Beagle dogs after inhalation of ^{91}Y in aluminosilicate particles, normalized to an ILB of 1 MBq ^{91}Y per kg body weight and average retention. Infinite beta dose factors for lung, skeleton and liver are 54, 0.22, and 0.055 Gy/MBq/kg, respectively.

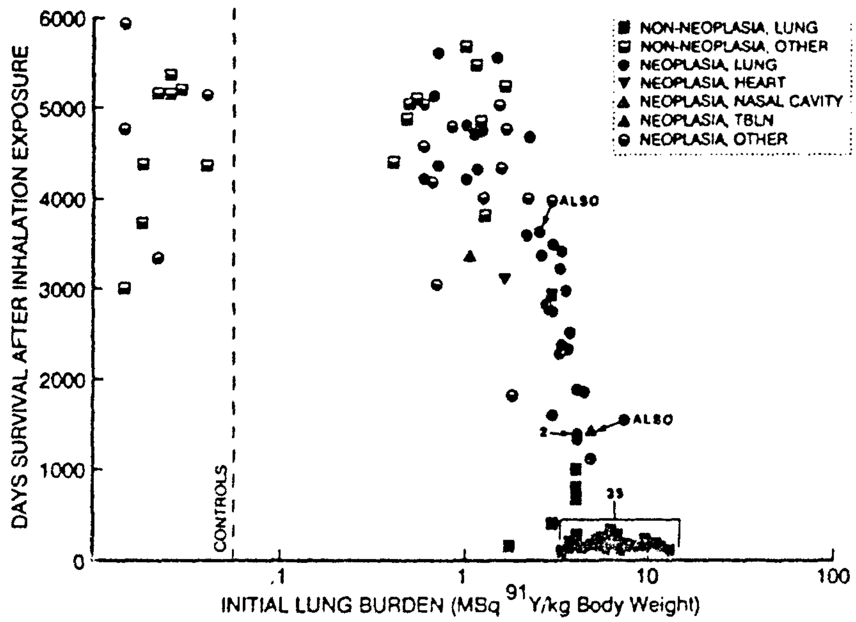

Figure 34. Relationship between initial lung burden of ^{91}Y and survival time for dogs that inhaled ^{91}Y in fused aluminosilicate particles. Principal lesions at death also noted.

and small airways of the lung. The histologic types were classified as bronchioloalveolar carcinoma, papillary adenocarcinoma, and combined squamous cell-bronchioloalveolar carcinoma. Metastases within the lung and to local lymph nodes were frequent but metastases outside the thorax were rare.

Tumors were also found in the nasal mucosa (1 dog), TBLN (1 dog), and heart (1 dog). These tumors were considered radiation-induced because of the ^{91}Y content of these tissues or their proximity to ^{91}Y-containing tissues and their rarity in control dogs. No tumors were noted in the liver or skeleton of any dog.

A proportional hazards model was used to estimate the relative risk of lung cancer, and from this model the absolute risks or life-time risks of lung cancer were calculated. The excess relative risk was the sum of a linear function and a power function (power of 7.8) of the time-dependent radiation dose to the lung. The control incidence of lung tumors was based on the current experience from the entire population of 242 control dogs on longevity studies. Below 60 Gy, the excess relative risk was linear, equaling 0.06 per Gy. The absolute risk per unit dose was 60 lung tumors per 10^4 Gy over the same range.

The lung is the organ predominantly affected after inhalation of ^{91}Y in a relatively insoluble form. With the exception of the TBLN, and possibly the nasal mucosa, the radiation doses to other organs are about a factor of 100 or more less than the dose to lung.

The histologic types of lung tumors seen were all epithelial in nature. The tumors were similar in phenotype to those seen with other inhaled alpha- or beta-emitting radionuclides. Pulmonary hemangiosarcomas, seen with high, protracted, beta-radiation doses, such as those from ^{144}Ce or ^{90}Sr (Hahn, F. F. *et al. J. Natl. Cancer Inst. 50*: 675, 1973), were not seen.

The proportional hazards model evaluation of the dose-response relationship indicated a linear dose response, at doses below 60 Gy. Such a linear dose response is consistent with the dose response for many biologic effects from beta irradiation.

The absolute risk factor of 60 lung tumors per 10^4 Gy is less than the risk factor for lung cancer derived from the Japanese A bomb survivors (Table 25). Models used in BEIR V to evaluate the current data from the life-span study of these survivors resulted in a risk factor of 125 lung tumors per 10^4 Gy for males exposed at

Table 25

Risk Factors for Lung Cancer Following Irradiation

Type of Exposure	Risk Factor[a]	Basis for Estimate[b]	Reference
Chronic beta-internally deposited	60	Dogs that inhaled ^{91}Y FAP	This paper
Acute gamma-external irradiation	125	A-Bomb survivors	NAS/NRC, 1990
Chronic alpha-internally deposited	2800	Dogs that inhaled $^{238}PuO_2$	Muggenburg, B. A. *et al.* In *Proceedings of the BOHS 7th International Symposium on Inhaled Particles*, Edinburgh, Scotland, Pergamon Press, 1992.

[a]Lung cancer per 10^4 Gy.
[b]Young adult dogs - 25 yr old humans.

25 years of age (NAS/NRC, 1990). The lower risk factor for inhaled ^{91}Y is probably due to the dose protraction that occurs with internally deposited radionuclides with half-lives longer than a few hours (Hahn, F. F. *et al. Radiat. Res. 96*: 505, 1983). The risk factor for inhaled alpha-emitting radionuclides, based on studies of dogs that inhaled $^{238}PuO_2$, is considerably higher than that for the inhaled beta emitter ^{91}Y (Table 25). The ratio of these two risk factors is about 45. This ratio compared to most ratios of high- vs. low-LET radiations (NCRP. *The Relative Biological Effectiveness of Radiations of Different Quality*, Report 104, National Council on Radiation Protection and Measurements, Bethesda, MD, 1990). For example, the ratio of ^{226}Ra vs. ^{90}Sr for bone sarcoma in dogs and mice is about 25. The reason for this seemingly high ratio is not known. Analysis of other studies with dogs exposed to inhaled radionuclides may shed more light on this subject.

For the evaluation of human exposure situations, however, the most important ratios are those related to brief, whole-body, photon irradiation so that the A-bomb survivor data can be used as a basis for comparison. Unfortunately, there are no data from dogs exposed to brief, whole-body photon radiation available for comparison to the human data base.

2. Biological Effects of $^{91}YCl_3$ Inhaled by Beagle Dogs

A. F. Hubbs, B. A. Muggenburg, F. F. Hahn, W. C. Griffith, and B. B. Boecker

This study was conducted to determine the life-span radiotoxicity of $^{91}YCl_3$ in Beagle dogs. Yttrium-91 is of interest as a beta-emitting radionuclide with a relatively short half-life that occurs in abundance in operating light-water nuclear reactors. After ^{91}Y is inhaled in relatively soluble chemical forms, it translocates from the pulmonary region primarily to liver and skeleton. It is, however, retained in the lung long enough to deliver a large portion of its dose to that organ. ^{91}Y was selected for study as a representative radionuclide because of its potential for human inhalation exposure in the event of a nuclear reactor accident.

Forty-two dogs, equal numbers of both sexes, inhaled aerosols of $^{91}YCl_3$. The dogs were 12 to 14 mo of age (399 ± 14 days) at the time of inhalation. In addition, 12 dogs inhaled the aerosol vector (controls). After inhalation, the dogs were whole-body counted for ^{91}Y activity to determine the IBB and the long-term retention of this radionuclide (Range of LTRB was 0.5 to 20 MBq/kg). Health effects were determined by daily observation of the dogs and by annual medical evaluations that included a physical examination, complete blood cell counts, selected serum chemistry determinations, radiographs, and a medical history review. Sick dogs were examined and appropriate tests conducted to establish a diagnosis. Diseases that appeared to be unrelated to the inhalation of ^{91}Y were treated by standard veterinary procedures. As the dogs died or were euthanized, complete necropsy and histopathology examinations were done. When all the animals in this study were dead, a final review of the pathology and clinical findings was conducted by a pathologist (A.H.) and clinician (B.M.) to establish and use uniform terminology and diagnostic criteria.

Early deaths, which occurred in 11 dogs from 12 to 33 days after inhalation, were primarily due to damage to the blood-forming cells in the bone marrow. Severe thrombocytopenia and leukocytopenia resulted in fatal hemorrhage or acute septicemia. In addition to the animals that died acutely, 21 dogs had moderate-to-severe changes in peripheral blood cell counts that indicated serious damage to the bone marrow. These changes included thrombocytopenia, neutropenia, lymphopenia, monocytopenia, and erythrocytopenia. A few of these dogs also had clinical signs of illness such as ecchymotic hemorrhages on mucous membranes.

The distributions of neoplastic and non-neoplastic diseases in different organ systems in the exposed and control dogs are given in Table 26. These diseases were classified as either the cause of death or major contributing diseases. A major contributing disease was defined as causing moderate-to-severe morphologic changes in tissues with detected clinical signs, a malignant tumor that metastasized, or a benign tumor that was life-threatening. In some dogs significant disease was present in more than one organ system and, therefore, dogs may have been counted more than once. Of the 31 dogs that survived the acute hematologic dyscrasia, 16 (52%) died from neoplasia, and 6 (14%) had tumors that were classified as major contributing diseases. In the control population, 6 (50%) died from neoplasia, and 1 (8%) dog had a tumor that was a major contributing disease. In the dogs that inhaled ^{91}Y, tumor incidence in the respiratory tract appeared to be higher than expected. The apparent increase in tumors in the digestive system is probably not significant because the tumors were found in different digestive organs, and only one tumor that might be related to radiation, an hepatocellular carcinoma, was found in the liver.

Beta dose resulting from the inhaled ^{91}Y was delivered mainly to the respiratory tract, liver, and skeleton. As indicated above, tumors of the respiratory tract were apparently increased in incidence, only one tumor was found in the liver, and no tumors were found in the skeleton. Effects that were observed in the skeleton occurred soon after the inhalation exposure and were associated with the bone marrow. Information on the tumors in the respiratory tract is given in Table 27. In three dogs, tumors were found in the nose. Two dogs died from lung tumors, and lung tumors were found incidentally in two other dogs.

Two control dogs and three dogs that inhaled $^{91}YCl_3$ had tumors of the mammary glands (not shown in Table 26). One exposed dog had two adrenocortical carcinomas, and three exposed dogs had thyroid carcinomas. One control dog had a thyroid carcinoma.

In summary, $^{91}YCl_3$ inhaled by dogs resulted in an increase in the incidence of tumors of the respiratory tract, both in the nasal epithelium and in the pulmonary region of the lung. The incidence of tumors of other organs did not appear to be increased. The effects on the skeleton were confined to the early effects on the bone marrow causing hematologic dyscrasia. Despite the wide gradation of dose to the skeleton in the 31 dogs that survived the early deaths, none of the dogs developed bone marrow or bone tumors. Although a wide range of doses to the liver occurred (0.65 to 10 Gy), only one liver tumor was found. This is too low an incidence to confidently ascribe this tumor to radiation effects. A much higher incidence of liver tumors and liver degeneration was observed in the studies of inhaled $^{144}CeCl_3$ and injected $^{137}CsCl$ in dogs that received similar cumulative beta doses to the liver (6.1 to 35 Gy).

Table 26

Primary Causes of Death and Major Contributing Diseases of Dogs Injected with $^{91}YCl_3$ and of Control Dogs

System	Neoplastic Disease[a]		Non-Neoplastic Disease[b]	
	$^{91}YCl_3$ Exposed	Control	$^{91}YCl_3$ Exposed	Control
Respiratory	5[c]	0	8[c]	0
Hematopoietic	0	0	12[c]	0
Digestive	6[c]	1	8[c]	3[c]
Urogenital	2[c]	1[c]	9[c]	5[c]
Nervous	0	0	5[c]	0
Cardiovascular	1[c]	1	12[c]	3[c]
Integument	5[c]	2[c]	0	0
Endocrine	6[c]	1	2[c]	1[c]
Skeletal	0	0	1[c]	1[c]
Other	0	0	4[c]	1

[a]Number represents the number of dogs that died with a neoplasm which was considered the primary cause of death or a major contributing disease. There were 46 dogs exposed to $^{91}YCl_3$ and 12 control dogs.
[b]Number represents the number of dogs that died with a non-neoplastic disease which was considered the primary cause of death or a major contributing disease.
[c]Dogs included in this total also appear in other categories.

Table 27

Occurrence of Cancers of the Respiratory Tracts in Dogs that Inhaled $^{91}YCl_3$ and Were Followed for Life-Span Observation

Tattoo	Relationship to Death	Site	Morphology
118A	PCOD	Nose, Epithelium	Carcinoma, Squamous Cell
134C	PCOD	Nose, Epithelium	Carcinoma, Squamous Cell
171F	PCOD	Nose, Epithelium	Carcinoma, Squamous Cell
173F	PCOD	Lung	Adenocarcinoma, Bronchioloalveolar w/Squamous Metaplasia
171B	INCD03	Lung, Right Cardiac Lobe	Adenocarcinoma, Papillary, Primary
171B	INCD02	Lung, Right Diaphragmatic Lobe	Adenocarcinoma, Papillary, Primary
119A	INCD04	Lung, Left Diaphragmatic Lobe	Adenocarcinoma, Papillary
173G	INCD02	Lung, Left Diaphragmatic Lobe	Adenocarcinoma, Bronchioloalveolar
174A	PCOD	Lung, Left Diaphragmatic Lobe	Adenocarcinoma, Papillary

PCOD = Primary Cause of Death
INCD = Incidental Findings

3. Late-Occurring Effects From Inhaled $^{238}PuO_2$ in Dogs

B. A. Muggenburg, R. A. Guilmette, W. C. Griffith, F. F. Hahn, N. A. Gillett*, and B. B. Boecker

Plutonium-238 is used as a thermal electrical energy source in spacecraft and in other applications in which a long-term power source is needed. It poses a potential hazard to humans during the manufacture of these power sources, in the accidental loss of containment from these devices, and from waste of certain nuclear power cycles. Fortunately, few individuals have been accidentally exposed to ^{238}Pu; therefore, it is necessary to obtain information concerning its toxicity from animal experiments. Inhalation was selected because it is the mostly likely route of human exposure in the event of an accidental airborne release. The study reported here was conducted in 144 Beagle dogs that inhaled monodisperse aerosols of $^{238}PuO_2$, and 24 dogs that inhaled only the aerosol vehicle. The aerosols were prepared using the method of Raabe *et al.* (*Health Phys. 28*: 655, 1975). Seventy-two dogs inhaled 1.5 μm activity median aerodynamic diameter (AMAD) particles, and 72 dogs inhaled 3.0 μm AMAD particles of $^{238}PuO_2$. The geometric standard deviations for these distributions were < 1.2, indicating monodisperse sizes. For each particle size, dogs were exposed to achieve one of the following graded activity levels of ILB: 21, 10, 5, 3, 1, or 0.4 kBq ^{238}Pu/kg body mass. The exposures resulted in ILBs of 37 to 0.11 kBq/kg body mass and from 55.5 to 0.37 kBq/kg body mass for the exposures to 1.5 μm AMAD and 3 μm AMAD particles, respectively.

Male and female dogs, 11 to 13 months old at the time of exposure, were used. All dogs were observed twice daily for health problems. Yearly physical examinations were given; radiographs of the head, chest, abdomen, and limbs taken; and blood drawn for cell counts and serum chemistry determinations. Sick dogs had diagnostic tests performed and except for tumors of the lung, liver, and skeleton, diseases were treated using accepted standard veterinary procedures. Dogs that had apparent fatal diseases or signs of discomfort were euthanized. A necropsy was performed on each dog after death; all major organs and all grossly apparent lesions were sampled for histopathology.

Average alpha doses to lung, skeleton, and liver were calculated using radiochemical analytical data for tissue and excreta by the methods of Mewhinney and Diel (*Health Phys. 45*: 39, 1983).

At the end of the study, the clinical records and pathology findings were reviewed by a pathologist and a veterinary clinician; final diagnoses were reached for all dogs. The findings were classified as: (1) primary cause of death; (2) major contributing disease; and (3) incidental findings.

The first lung tumor was detected in a dog euthanized because of severe radiation pneumonitis at 966 days post-inhalation exposure (DPE), and the first death due to a lung tumor occurred at 1319 DPE. Lung tumors were detected in 47 dogs (Table 28); of this group, lung tumor was the primary cause of death in eight dogs that died from 3.6 to 12.3 years after plutonium exposure (Fig. 35). Twenty-seven dogs that died from bone tumors also had lung tumors. The phenotypes of these tumors were primarily bronchioloalveolar carcinomas and papillary adenocarcinomas that arose in the pulmonary region of the lung.

Skeletal tumors comprised the majority (92 dogs) of the tumors found in the exposed dogs. These tumors were primarily osteosarcomas that occurred with some site preference in the axial skeleton and head of the humerus. The first tumor was detected in a dog that died 1125 DPE. Eighty-nine dogs with bone tumors as the primary cause of death (Table 29) died from 3.1 to 13.2 years after inhalation of plutonium (Fig. 1); 22 of the 89 dogs also had additional primary bone tumors (Table 29).

Liver tumors were detected in 19 dogs and caused the death of two dogs at 6.6 and 13.2 years after plutonium inhalation (Table 30). In 12 dogs, liver tumors were a major contributing factor in deaths from either bone or lung tumors. Thirteen of the 19 dogs had a variety of malignant liver tumors; 6 had only benign liver tumors. Risk estimates were calculated using only dogs with malignant tumors.

*Currently at Genentech, Inc., San Francisco, California.

Table 28

Number of Dogs with Lung Tumors after Inhalation of $^{238}PuO_2$ Aerosols or Control Exposures to the Aerosol Vehicle

	Exposed	Control
Primary Cause of Death[a]	8	2
Major Contributing Disease		
with bone tumors as PCD[b]	27	0
with liver tumors as PCD[b]	2	0
with other diseases as PCD[b]	6	0
Incidental Finding	4	0
Total Dogs with lung tumors	47	2

[a]Two dogs with lung tumors as the primary cause of death also had other primary lung tumors of different phenotypes.
[b]PCD = primary cause of death.

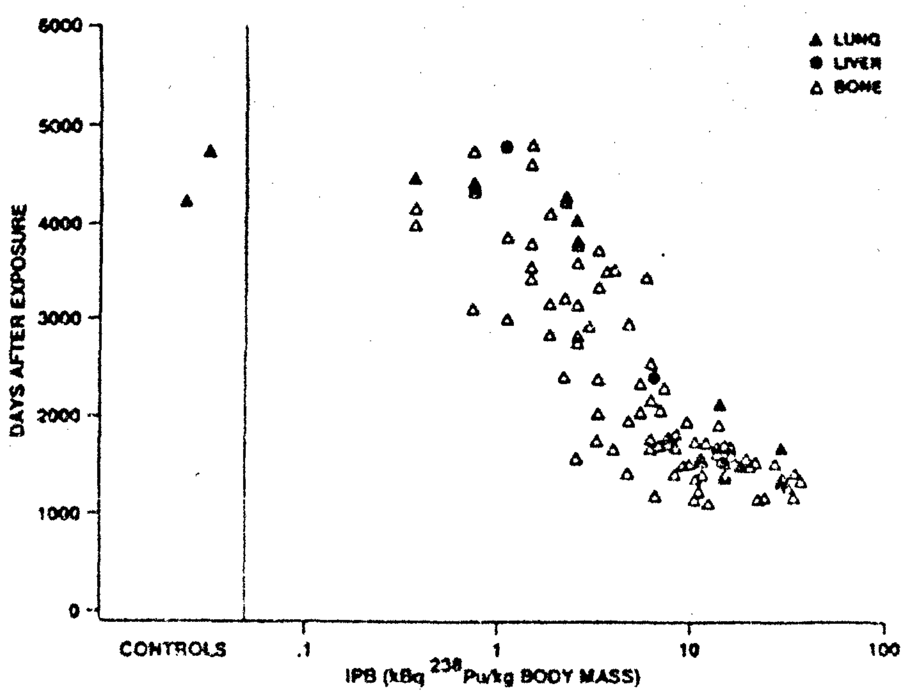

Figure 35. The time of death of individual dogs with lung (8), bone (89), or liver (2) tumors as the primary cause of death is given in relationship to the initial lung burden of $^{238}PuO_2$. The control dogs are also shown.

Table 29

Number of Dogs with Bone Tumors after Inhalation of $^{238}PuO_2$ Aerosols or Control Exposures to the Aerosol Vehicle

	Exposed	Control
Primary Cause of Death[a]	89	0
Major Contributing Disease		
with liver tumors as PCD[b]	1	0
with lung tumors as PCD[b]	1	0
with other diseases as PCD[b]	1	0
Total Dogs with bone tumors	92	0

[a]Twenty two dogs had more than one primary bone tumor, and one of the bone tumors was the cause of death.
[b]PCD = primary cause of death.

Table 30

Number of Dogs with Liver Tumors after Inhalation of $^{238}PuO_2$ Aerosols or Control Exposures to the Aerosol Vehicle

	Exposed	Control
Primary Cause of Death	2	0
Major Contributing Disease		
with bone tumors as PCD[a,b]	9	0
with lung tumors as PCD[a,b]	3	0
with other diseases as PCD[a,b]	5	1[c]
Total Dogs with liver tumors[a]	19	2

[a]Some dogs had multiple primary liver tumors of different phenotypes.
[b]PCD = primary cause of death.
[c]Adenoma of the liver.

As shown in Figure 35, lung and bone tumors as the cause of death appeared over similar ranges of ILB and times after exposure. Fatal liver tumors occurred at a somewhat lower ILB and at longer times after plutonium exposure than lung and bone tumors. The first dog died from a liver tumor at 6.6 yr after plutonium inhalation in comparison to 3.6 yr for lung and 3.1 yr for bone tumors.

Based upon the age-specific incidence of the tumors, a proportional hazards model was used to estimate the relative risk as the ratio of changes in the age-specific incidence as a function of the radistion dose. The model used nonparametric estimates of the baseline hazard and additive linear functions of the radiation dose for

the relative risk, similar to the methods used in the BEIR V Report (NAS/NRC. *Health Effects of Exposure to Low Levels of Ionizing Radiation*, National Academy Press, Washington, DC, 1990). Because the relative risk was a linear function of the dose for dogs that had an ILB of less than 7 kBq/kg body mass, dogs exposed above this level were not used in the risk estimates. The lifetime risks were estimated at low radiation doses, since at this level increased mortality from competing causes other than tumors in the lung, liver, and bone would be unlikely. The mortality rates from these competing causes were estimated from the control dogs. This rate was combined with the increased incidence for lung, liver, or bone cancer to calculate the excess cancers over the life span of the dog.

The estimated lifetime risks are 280 lung cancers/10^3 Gy, 80 liver cancers/10^3 Gy, and 620 bone cancers/ 10^3 Gy. These estimates are based upon the occurrence of malignant tumors and time to initial diagnosis of tumor formation judged from periodic radiographs of the dogs.

The original expectation in this study was that the particles of $^{238}PuO_2$ would be retained in the lung for very long times like particles of $^{239}PuO_2$, resulting in chronic irradiation of lung tissues. It was quickly realized that the $^{238}PuO_2$ plutonium particles were dissolving, and the ^{238}Pu was being translocated to liver and skeleton. Diel and Mewhinney (*Health Phys. 44*: 135, 1983) hypothesized that the particles fragmented because of the absorbed alpha dose within particles related to high specific activity of the ^{238}Pu. The resulting dose pattern included the lung, skeleton, and liver as organs receiving relatively high alpha doses (Mewhinney and Diel, 1983). These organs then expressed the majority of the late biological effects observed in this experiment, tumors of the lung, skeleton, and liver. Bone and lung tumors were expressed first and dominated the cause of death for the first 6 years (Hahn, F. F. *et al. J. Natl. Cancer Inst. 67*: 917, 1981). Liver tumors became important in the final years of this study, but many of these were not the primary cause of death (Gillett, N. A. *et al. Am. J. Pathol. 133*: 265, 1988). Bone and liver tumors have been observed in other studies in which dogs have inhaled $^{238}PuO_2$ or been injected with soluble forms of ^{239}Pu (Dagle, G. E. *et al.* In *Life-Span Radiation Effects Studies in Animals: What Can They Tell Us?* [R. C. Thompson and J. A. Mahaffey, eds.], p. 471, OSTI, USDOE, 1986; Wrenn, M. E. *et al.* In *Life-Span Radiation Effects Studies in Animals: What Can They Tell Us?* [R. C. Thompson and J. A. Mahaffey, eds.], p. 32, OSTI, USDOE, 1986). In these studies, as in our study, liver tumors appeared later than bone tumors (Taylor, G. N. *et al.* In *Life-Span Radiation Effects Studies in Animals: What Can They Tell Us?* [R. C. Thompson and J. A. Mahaffey, eds.], p. 268, OSTI, USDOE, 1986.)

These results have important implications for the estimate of risk to humans that inhale aerosols of ^{238}Pu, because dose patterns are probably similar in dogs and humans (International Commission on Radiological Protection [ICRP], *The Metabolism of Plutonium and Related Elements, Ann. ICRP 16*, 1986). Risk estimates for alpha-emitting radionuclides for humans are 70 lung cancers/10^3 person-Gy for underground miners, 20 bone cancers/ 10^3 person-Gy for ^{224}Ra-injected patients, and 30 liver cancers/10^3 person-Gy for Thorotrast patients (NAS/NRC, 1990). These risk estimates are lower than those for dogs in this experiment. This may be due to true species differences or an underestimation of risks for plutonium in humans. Risk considerations must include bone and liver as important possible consequences in human accident cases, and the effects of retention of ^{238}Pu in the lung should be considered as different from ^{239}Pu.

4. Long-Term Effects of Repeated Inhalation Exposures of Dogs to $^{239}PuO_2$: A Preliminary Report

J. H. Diel, B. A. Muggenburg, F. F. Hahn, I. Y. Chang, and R. A. Guilmette

Plutonium-239 is a relatively abundant, manmade, alpha-emitting isotope used in nuclear reactors and explosive devices. The production and handling of this material carries the potential for inhalation exposures to respirable aerosols, particularly in the dioxide form. Many studies have examined the health effects of inhaled $^{239}PuO_2$. The primary health effect observed in such studies is radiation pneumonitis or pulmonary fibrosis at early times and lung cancer at later times. There is some evidence that, as in the case of beta or gamma radiation, dose rate influences the effectiveness of internal alpha emissions in producing lung cancer.

This paper examines the relationship between the dose rate and the production of lung cancer in Beagle dogs exposed once, resulting in a decreasing dose rate pattern with time, and dogs exposed repeatedly, resulting in an increasing dose rate pattern with time. Exposure levels were chosen such that the two groups would receive approximately equal doses over their lifetimes and so that no acute effects were expected. In this study, the dogs received single or repeated pernasal inhalation exposures to 0.75 μm aerodynamic diameter monodisperse aerosols of $^{239}PuO_2$ and were maintained for their lifetime to observe the biological effects of these exposures.

Dogs used in these studies were young adult, purebred Beagles raised in the Institute's colony. Equal numbers of males and females were used. Each dog was physically evaluated before initial exposure to assure its general good health and fitness for inclusion in the study. Dogs were first exposed at about 1 year of age.

Exposure methods for this study have been reported (Diel, J. H. *et al. Radiat. Res.*, in press). The 23 dogs exposed once received an average of 0.80 $\pm$ 0.31 kBq per kg body mass ($\pm$ standard deviation) of Pu in their one exposure to an aerosol of $^{239}PuO_2$. Thereafter, they were sham exposed semi-annually. Dogs exposed repeatedly were exposed to aerosols of $^{239}PuO_2$ semiannually. Exposures were continued for 20 exposures or until the dogs were either euthanized, died, or were judged in sufficiently poor health to be at risk from the exposure procedure. Each dog was exposed between 12 and 20 times (mean = 18). The 23 dogs received an average of 0.069 $\pm$ 0.044 kBq per kg body mass per exposure. (One dog exposed once was overexposed and died prematurely of radiation pneumonitis and pulmonary fibrosis. One repeatedly exposed dog died accidentally during its second exposure. These two dogs are not considered in the analysis and are not included in the above totals.)

A gamma-emitter, ^{169}Yb, was incorporated into the $^{239}PuO_2$ particles as a radioactive tag to measure initial deposition and early retention by whole-body counting. Four dogs exposed once and four exposed repeatedly had excreta collected periodically after exposure up to their time of death to aid in dose calculations. Lung, liver, tracheobronchial lymphnodes, mediastinal lymph nodes, mediastinal tissue, femur, humerus, and lumbar vertebrae taken at necropsy were assayed radiochemically for Pu content on all dogs. An analysis of samples from all tissues was carried out on a small group of dogs to confirm that the vast majority of the Pu activity was located in the tissues analyzed for all dogs.

Only the dosimetry of the lung is described because the activity found in tissues other than the lung and associated lymph nodes was less than 5% of the body burden, and all radiation effects making major contributions to the deaths of the animals occurred in the lung.

The clearance of Pu from the lungs of dogs exposed once is characterized by a two-component, negative-exponential clearance equation where 71% of the material is cleared with a half time of 315 days and the remainder with a half time of 9400 days. This clearance equation is based on the initial and final lung burdens of dogs exposed once and on similar data for dogs sacrificed in a single exposure dosimetry study reported previously (Guilmette, R. A. *et al. Int. J. Radiat. Biol. 45*: 563, 1984).

The clearance of Pu from the lungs of dogs repeatedly exposed to Pu was calculated using the assumption that the clearance for each exposure was the same as for the dogs exposed once. This method of calculation resulted in good agreement between the calculated lung burden at death and the lung burden measured by radiochemical analysis of the lung. The resulting lung burdens and dose rates for both single and repeated exposures are shown in Figure 36 for hypothetical dogs receiving lung burdens equal to the average per exposure for each study.

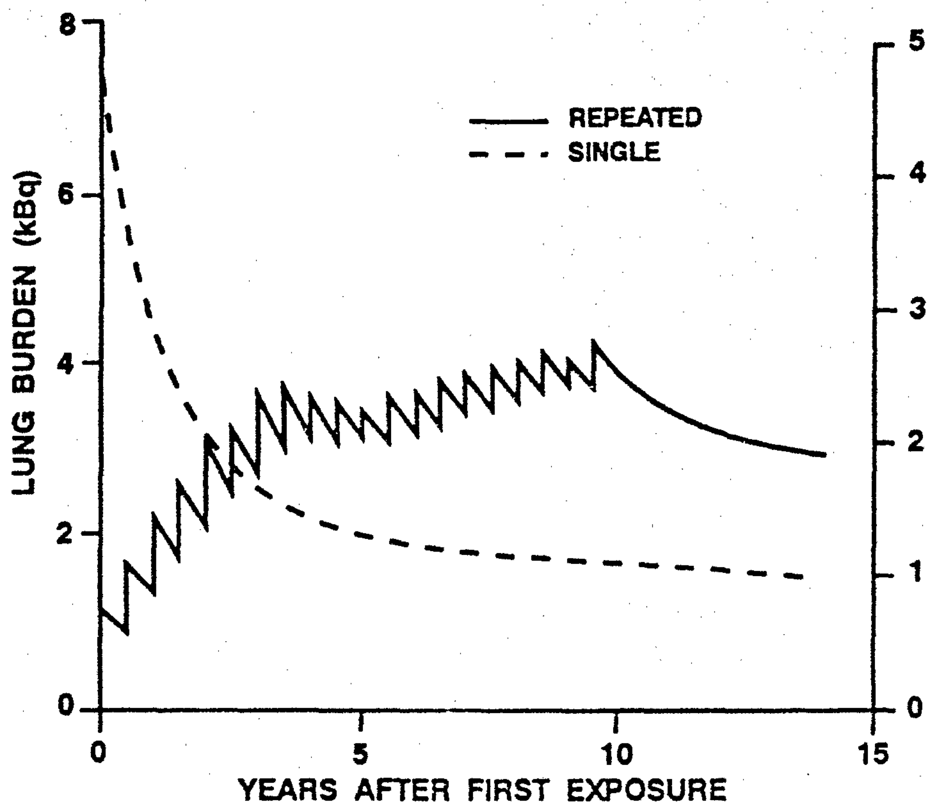

Figure 36. Comparison of lung burdens and dose rates for dogs exposed once or repeatedly by inhalation to 0.75 μm aerodynamic diameter aerosols of $^{239}PuO_2$. Curves represent calculations for dogs exposed to the average activity in each exposure.

Dogs exposed once lived an average of 10.4 $\pm$ 2.8 yr ($\pm$ standard deviation) after exposure and received an average dose of 6.7 $\pm$ 3.0 Gy to lung. Dogs exposed repeatedly lived an average of 9.8 $\pm$ 1.9 yr after first exposure and received a dose of 7.4 $\pm$ 2.3 Gy to lung.

The most common pathologic finding among the dogs was lung cancer. Sixteen of the dogs exposed once died with this effect as did 16 of the repeatedly exposed dogs. Other, presumably non-radiation related, cancers occurred in other organs as would be expected in any population of dogs living this long, based on controls grouped from other studies. These included two dogs exposed once, one with a disseminated sarcoma and the other with a mammary gland adenocarcinoma, and four dogs exposed repeatedly that died with a pituitary carcinoma, a transitional cell carcinoma of the bladder, an hemangiosarcoma of the vertebra and a melanoma of the oropharynx, respectively. Dogs dying of noncancerous effects included three dogs exposed once and three dogs exposed repeatedly. The primary diagnoses on these dogs included congestive heart failure, immune hemolytic anemia, vertebral disc herniation, ruptured gall bladder, bronchopneumonia, and accidental death. Two of the dogs exposed only once are still alive. Figure 37 shows the survival times and primary findings at death of the dogs in this study.

The parameter used to compare the effectiveness of the two modes of exposure was the time from first or only exposure to death with lung cancer. This health effect was chosen because it is the dominant effect in this study and the primary effect expected from inhalation of insoluble radioactive materials deposited in deep lung. The Cox proportional hazards model (Cox, D. R. *Biometrika 62*: 269, 1975) was used for the comparison of the two modes of exposure. The model considers all causes of death, so that all dogs are used in the analysis. It was found that the survival time after first or only exposure to death with lung cancer does not depend on whether the animal was exposed once or semiannually (p = 0.31). Based on this preliminary analysis, for dogs

exposed either once or repeatedly to obtain a decreasing or increasing alpha dose rate with time, the survival of animals dying from lung cancer appears to be independent of dose rate and depended only on the total cumulative radiation dose to lung. Thus, at least for this case based on this preliminary analysis, the dose rate does not influence the effectiveness of alpha radiation in the production of lung cancer. The final detailed analysis of this study will be completed when all dogs are dead and the medical records are reviewed.

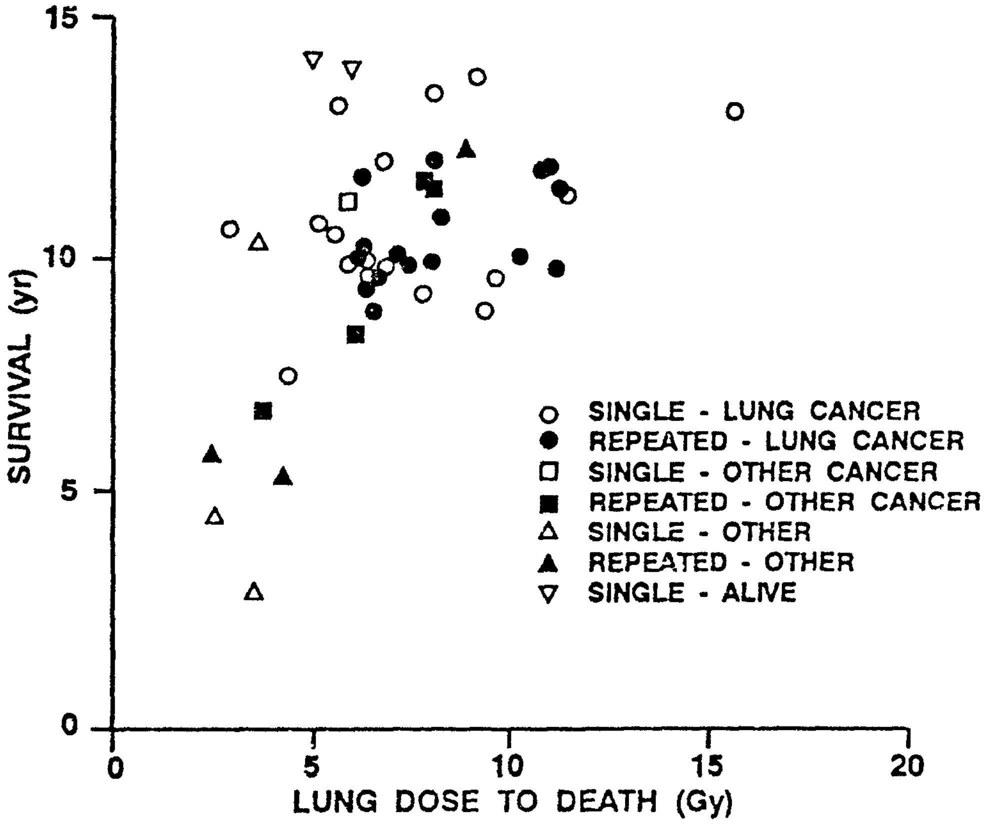

Figure 37. Survival of dogs exposed by inhalation to 0.75 μm diameter aerosols of $^{239}PuO_2$. Circles represent dogs dying of lung cancer; squares represent dogs dying of other cancers; triangles represent dogs dying of other causes; and inverted triangles represent live dogs. Empty symbols indicate single exposures, and filled symbols refer to repeated exposures.

5. Interspecies Comparison of Lung Tumor Incidence in Laboratory Animals Exposed by Inhalation to ^{144}Ce in Insoluble Particles

B. B. Boecker, W. C. Griffith, F. F. Hahn, D. L. Lundgren, and B. A. Muggenburg

Fission product radionuclides were the type of radionuclides first studied at ITRI to determine the life-span health risks of inhaled radionuclides, the influence of various dose and effect modifying factors, and to extrapolate these results to possible human inhalation exposures for which no direct human data exist. The radionuclide ^{144}Ce* has been used for a number of these studies as a "typical" fission product with a moderately long radioactive half-life (284 days) and energetic beta emissions ($E = 1.27$ MeV). Studies in which ^{144}Ce has been used in dogs include investigations of solubility effects in young adults, age-related effects, repeated exposure studies, and alpha-to-beta comparison studies with ^{239}Pu. This report is an interspecies analysis of life-span lung tumor incidences seen in mice, rats, and dogs after inhalation of ^{144}Ce in a relatively insoluble form. This preliminary analysis is then used to estimate a lung cancer risk factor for persons exposed to chronic beta radiation from radionuclides deposited in their lungs.

In the three studies discussed, the animals were exposed once, briefly, by inhalation to aerosols of $^{144}CeO_2$ (C57Bl/6J mice or F344/Crl rats) or ^{144}Ce in fused aluminosilicate particles, FAP, (Beagle dogs) and maintained for life-span observation. Multiple dose levels were included in each study to investigate the dose-response relationship. Detailed methodology for these studies has been given for mice in Lundgren, D. L. *et al. Health Phys. 38*: 643, 1980; for rats in Lundgren, D. L. *et al. Radiat. Res.* (in press); and for dogs, in the 1969-70 Annual Report, p. 183. Average doses to the lungs and other target organs were computed from each animal's whole-body retention data and tissue distribution data observed in animals that inhaled ^{144}Ce in a similar form in parallel serial sacrifice studies. Biological effects were observed during life, at necropsy and by histopathological examinations of tissue specimens. Because the dog studies are being reviewed by a pathologist and a veterinary clinician to develop final diagnoses, this study is still considered to be in progress. Proportional hazards methodology was used to analyze and compare the dose-response patterns observed for the different species used in these studies (Kalbfleisch, J. D. and R. L. Prentice. *The Statistical Analysis of Failure Time Data*, Wiley, New York, p. 55, 1980).

Some numerical details relating to these studies are given in Table 31. The number of exposed animals ranged between 100 and 200 and the controls between 100 and 400 in each study. Figure 38 shows the patterns of average pulmonary retention of ^{144}Ce seen in these three species. As has also been seen in studies with other inhaled aerosols, the rats and mice had a prolonged early clearance phase that was minimal in the dogs, resulting

Table 31

Experimental Design and Dosimetry Factors for Laboratory Animals that Inhaled a Relatively Insoluble Form of ^{144}Ce and were Maintained for Life-Span Observations

	Number of Animals			Committed Dose to Lung	
Species[a]	Exposed	Control	ILB (kBq/kg)[b]	Time to 95% (y)	Total Dose (Gy/kBq/kg)
Mouse	178	400	370-8400	0.95	0.024
Rat	180	115	10-1200	0.95	0.031
Dog	111	117	0.09-7800	2.5	0.17

[a]Mice were C57Bl/6J, rats were F344/Crl and dogs were Beagles.
[b]Initial lung burden expressed as kBq of ^{144}Ce activity in the lung per kg of body mass.

*In this report, use of the term ^{144}Ce refers to an equilibrium mixture of ^{144}Ce-^{144}Pr

in a long-term retention component in the rodents that represented 1/10 or less of the magnitude of the long-term retention component in the dogs. These differences in pulmonary retention were reflected in the calculated doses. Because of the relatively fast clearance of ^{144}Ce from lungs of the mice and rats, they received 95% of the committed or infinite absorbed beta dose in about 0.95 yr. In the dogs, for which pulmonary retention was more prolonged, it took 2.5 yr to reach 95% of the committed dose, resulting in a normalized dose commitment factor (dose to lung divided by the initial lung burden) that was about 5 times larger than seen in mice or rats (Table 31).

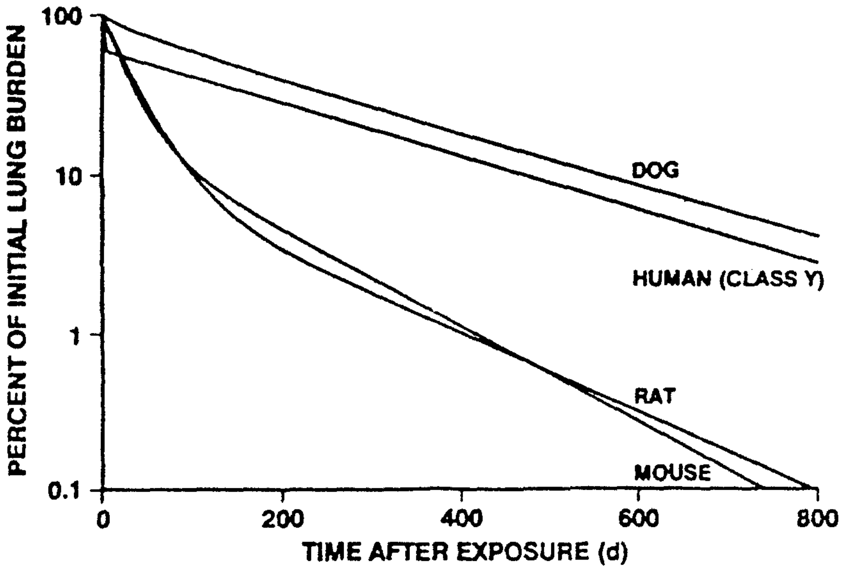

Figure 38. Pulmonary retention of ^{144}Ce inhaled in relatively insoluble forms by the mouse, rat and dog. These curves are uncorrected for radioactive decay. For comparison, the pulmonary retention of an ICRP class Y material in humans is also shown (ICRP Publication 30, Ann. ICRP 2, 1979).

Table 32 gives the total number of lung tumors seen and the relative distribution of tumor types for each species. For mice, the predominant tumor types were adenomas and adenocarcinomas; for rats, adenocarcinomas

Table 32

Relative Distribution of Lung Tumor Types Seen in Mice, Rats, and Dogs that Inhaled a Relatively Insoluble Form of ^{144}Ce and were Maintained for Life-Span Observations

	Percent of Tumor Totals		
Lung Tumor Type	Mice (75 Tumors)	Rats (23 Tumors)	Dogs (27 Tumors)[a]
Adenoma	65	13	0
Adenocarcinoma	28	61	63
Squamous Cell Carcinoma	4	22	0
Hemangiosarcoma	3	4	30
Other Sarcomas	0	0	7

[a]Analyses of the dog data are still in progress.

and squamous cell carcinomas; and for dogs, adenocarcinomas and hemangiosarcomas. The dose-response analyses given below are based on the numbers of animals with lung tumors. The hemangiosarcomas and other sarcomas were not included because they usually occurred earlier and at higher doses than the carcinomas. Because adenomas in mice are considered to be precursors of adenocarcinomas, and the same may be true for rats, adenomas were included in the analyses.

The proportional hazards calculation of relative and absolute risks was made using relationships (1) - (3).

$$\text{Proportional hazards: } k(t) = k_o(t)\,(1 + \beta D(t)) \tag{1}$$

In this relationship, $k(t)$ is the total age-specific lung tumor incidence rate, $k_o(t)$ is the background lung tumor incidence rate, β is the relative risk coefficient, and $D(t)$ is the cumulative absorbed beta dose to lung to time t. The relative and lifetime risks are:

$$\text{Linear relative risk} = 1 + \beta D(t) \tag{2}$$

$$\text{Lifetime risk} = \frac{1}{D} \int_o^T S(t)\,(\lambda(t) - \lambda_o(t))\,dt, \tag{3}$$

where $S(t)$ is the fractional survival at time t.

Figure 39 gives a plot of the estimated lifetime risks of developing a lung carcinoma as a function of absorbed dose. The close agreement in the responses of these three species is apparent. Numerical values for the lifetime risk factors for lung cancers, corresponding to slopes of these lines, are given in Table 33. These lifetime risk factors were quite consistent among species, ranging from 55 to 88 lung cancers/10^4 Gy, a factor of 1.5 from lowest to highest. This consistency occurred among three species of laboratory animals differing greatly in body size, life span, pulmonary retention and dose patterns. Also included in Table 3 are values for

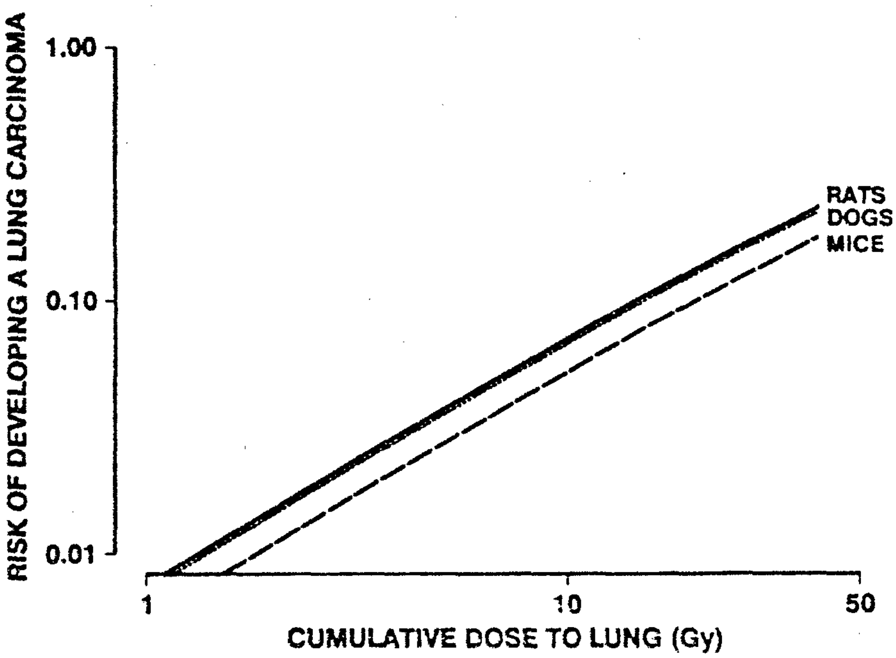

Figure 39. Lifetime risk of developing lung cancer from chronic beta irradiation resulting from a brief inhalation exposure to a relatively insoluble form of ^{144}Ce. All three species were observed over their entire life spans. Risks were calculated using proportional hazards methods.

the relative risk factors (β). These relative risk factors were less consistent among species than the lifetime risk factors, ranging from 0.10 to 0.50 /Gy, a factor of 5. The consistency among lifetime risk factors compared with relative risk factors indicates that the lifetime risk basis may be the best way to compare, across species, lung tumor risks from chronic beta irradiation.

Table 33

Species Characteristics, Dose Commitment Factors and Lung Cancer Risk Factors (Lifetime and Relative) for Laboratory Animals that Inhaled ^{144}Ce in a Relatively Insoluble Form

Species	Body Mass (kg)	Median Life Span (yr)	Lung Dose Commitment (Gy/kBq/kg)	Risk Factors	
				Lifetime[a]	Relative[b]
Mouse	0.018	2.1	0.024	55	0.35
Rat	0.20	2.2	0.031	88	0.50
Dog	10	14	0.17	70	0.10

[a]Lung cancers/10^4 Gy.
[b]Relative risk/Gy (β).

If one assumes that the lifetime risk approach is the best way to compare these lung cancer risks over different species, what is a reasonable way to extrapolate from chronic beta irradiation to human lung cancer risks? The consistency of values among the species studied indicates that the best approach at the present time is to assume that the mean of the risk factors seen in the species, 71 lung cancers/10^4 Gy, applies directly as the human lung cancer risk factor for chronic beta irradiation.

Although no human data are available from which to directly compute a lung cancer risk factor for chronic beta irradiation, lung cancer data from the Japanese atomic bomb survivors are available for acute external gamma irradiation. Table 4-3 in the BEIR V Committee Report, *Health Effects of Exposure to Low Levels of Ionizing Radiation*, National Academy Press, Washington, DC, 1990, gives the risk for cancers in various organs as a function of age at exposure. Using a human age of 25 y to correspond with the young-adult status of the animals used in this study, one finds a risk factor of 125 lung cancers/10^4 Sv, which for low-LET radiation is the same as 125 lung cancers/10^4 Gy. A direct comparison of this risk factor with the risk factor of 71 lung cancers/ 10^4 Gy indicates that chronic beta radiation may be less effective than acute gamma radiation by a factor of about 2. This difference can be considered as a dose-rate effectiveness factor, DREF, between low-LET radiations delivered (a) briefly at a high rate and (b) over a prolonged period at a low rate. The BEIR V Report and other sources indicate that DREF factors may be between 2 and 10. Our current estimate, which is consistent with the lower end of this range, indicates that prolonged beta irradiation of the lung is less effective than comparable radiation given briefly at a high rate.

In summary, lung cancer was the major long-term health effect seen in mice, rats, and dogs that inhaled relatively insoluble forms of ^{144}Ce. When the proportional hazard method was used to analyze the risks of lung cancer in these studies, similar lifetime risk factors were found for all three species. This consistency among species increased our confidence that the mean lifetime lung cancer risk factor, 71 lung cancers/10^4 Gy, could be used directly as an estimate of the lung cancer risk factor for humans that receive chronic beta irradiation of the pulmonary region. This risk factor is about one-half that given in the BEIR V Report for acute gamma exposure of the lung, implying a DREF of 2 for chronic beta irradiation.

6. Comparison of Inhaled $^{239}PuO_2$ and ß-Emitting Radionuclides on the Incidence of Lung Carcinomas in Laboratory Animals

F. F. Hahn, W. C. Griffith, B. B. Boecker, B. A. Muggenburg, and D. L. Lundgren

Irradiation of the lung in sufficiently high doses is known to result in lung carcinomas. This result has been demonstrated in populations of patients with ankylosing spondylosis treated with thoracic irradiation, in survivors of atomic bomb explosions in Japan, and underground miners exposed to radon and radon daughter products. None of these situations, however, directly applies to chronic alpha or beta irradiation of the deep, or alveolar, portions of the lung. Such can occur if individuals inhale radioactive particles released in reactor accidents or waste transportation accidents. No human populations are available for study that have inhaled particles of alpha- or beta-emitting radionuclides which deposit deep in the lung. To address this, studies were initiated at ITRI to establish the dose-response relationships resulting from the inhalation of plutonium dioxide or beta-emitting radionuclides with different radioactive halflives. This paper briefly summarizes the dose-response for lung carcinomas induced by these types of lung irradiation.

Details of the experimental design, animal exposure, dosimetry, and husbandry techniques have been reported. (McClellan, R. O. *et al.* In *Life-Span Radiation Effects in Animals. What Can They Tell Us?* OSTI, U. S. DOE, Oak Ridge, TN, p. 74, 1986; Lundgren, D. L., F. F. Hahn *et al. Radiat. Res.*, in press; Lundgren, D. L., P. J. Haley *et al. Radiat. Res.*, in press.) Beagle dogs were exposed briefly, per nasum, to aerosols of $^{239}PuO_2$ of different monodisperse particle sizes or ^{90}Y, ^{91}Y, ^{144}Ce or ^{90}Sr in relatively insoluble forms. F344 rats were similarly exposed but only to aerosols of $^{239}PuO_2$ or $^{144}CeO_2$. The animals were observed for their life spans to observe resulting biologic effects. All animals have died, except for some of the dogs exposed to $^{239}PuO_2$. The incidence rate for lung carcinomas was modeled as the observed time course for the appearance of carcinomas using a proportional hazard rate model. The proportional hazards calculation of relative and absolute risks was made using the following relationships:

$$\text{Proportional hazards: } \lambda(t) = \lambda_0(t)\ (1 + \beta D(t))\ .$$

In this relationship, k(t) is the age-specific lung tumor incidence rate at dose D(t), $k_0(t)$ is the background lung tumor incidence rate, ß is the relative risk coefficient, and D(t) is the time-dependent, cumulative absorbed dose to the lung. The relative and lifetime absolute risks are:

$$\text{Relative risk per Gy} = \beta$$

$$\text{Life-time risk per Gy} = \frac{1}{D(t)} \int_0^t S(\tau)\ (\lambda(\tau) - \lambda_o(\tau)) d\tau\ ,$$

where S(s) is the fractional survival at time s. This method is similar to the techniques used in the BEIR IV and BEIR V models of risk analysis.

The biological effects from these exposures have been documented elsewhere. (Lundgren, D. L., *et al. Radiat. Res.*, in press; Lundgren, D. L., F. F. Hahn and J. Diel, *Radiat. Res.*, submitted; Hahn, F. F. and D. L. Lundgren, *Radiat. Res.*, in press; Annual Report on Long-Term Dose-Response Studies of Inhaled or Injected Radionuclides (B. B. Boecker *et al.*, eds.), LMF 130, 1991.) Briefly, at the highest doses, animals died within months to 3 yr with pulmonary injury. Those living longer (rats > 1 year, dogs > 2 years) developed a high incidence of lung tumors. Table 34 gives the total number of lung tumors seen, the relative distribution of tumor types for each species and the types of radiation. The predominant tumor types were, for rats, adenocarcinomas and squamous cell carcinomas and, for dogs, adenocarcinomas and hemangiosarcomas. The hemangiosarcomas and other sarcomas are unusual tumors and occurred at higher doses. The dose-response analyses are based on the carcinoma incidences.

Table 34

Distribution (Percent) of Lung Tumor Types in Animals that Inhaled Radionuclides and Were Observed for Life Span

	Rats		Dogs	
Lung Tumor Type	α-emitters	ß-emitters	α-emitters	ß-emitters
Number of Tumors	172	24	108	110
Adenoma	9	13	1	2
Adenocarcinoma	70	62	96	59
Squamous Cell Carcinoma	19	21	<1	9
Hemangiosarcoma	1	4	0	25
Other Sarcomas	1	0	2	5

For dogs, the relative risk was estimated by summing a linear function of dose and a power function of dose. The power function applies to the higher doses, and the linear function of dose predominates over the power function at doses below 5 Gy for beta irradiation and 0.5 Gy for alpha irradiation (Fig. 40). These analyses show a reasonable agreement between the lifetime risks for lung carcinomas for rats and dogs for both alpha- and beta-emitting radionuclides.

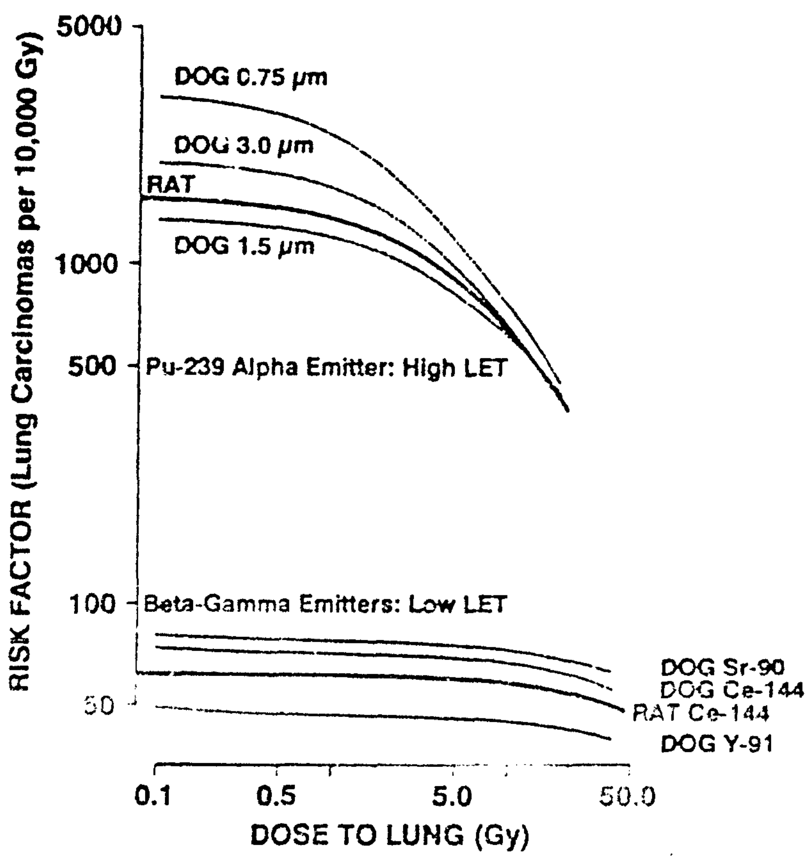

Figure 40. Risk factors for lung carcinomas in dogs and rats that inhaled $^{239}PuO_2$ or beta-emitting radionuclides.

Lifetime risks of lung carcinomas were calculated by integrating, over the lifetime, the sum of the estimated lung carcinoma incidence rate at 1 Gy from the proportional hazard rate model and the mortality rate for competing causes of death in the control animals. The dose of 1 Gy was used because it did not cause an increase in competing causes of death. The lifetime risks of lung carcinomas per 10^4 Gy for beta-emitting radionuclides were 60 for rats and 65 for dogs. For $^{239}PuO_2$ the lifetime risk was 1520 for rats and 2300 for dogs. The ratio of $^{239}PuO_2$ risk to beta-emitter risk was 25 for rats and 36 for dogs. Although these ratios are higher than the presently accepted quality factor of 20 for alpha and x-irradiation, the uncertainties in this analysis would not exclude a value of 20. On the other hand, the results may indicate that the quality factor of 20 is too low for comparing radiation-induced lung carcinoma incidence of alpha irradiation with that of beta irradiation.

7. Comparison of Bone Lesions Induced by Inhaled $^{90}SrCl_2$ or $^{238}PuO_2$

F. F. Hahn, N. A. Gillett*, B. B. Boecker, R. A. Guilmette, and B. A. Muggenburg

Radionuclides inhaled in a soluble form translocate from the lung to other organs of the body. A frequent site of deposition and retention is the skeleton. If the dose delivered to the skeleton is high enough, bone tumors may result. Both $^{90}SrCl_2$ and $^{238}PuO_2$ are radionuclides that have induced bone neoplasms in Beagle dogs after inhalation exposure. In this paper, we compare and contrast the bone tumors induced by these two radionuclides. The tumors have emissions with widely different energy and linear energy transfer characteristics.

Results were compared from two large dose-response studies involving dogs that inhaled radionuclides. Details of experimental design, exposure methods, husbandry and results of the specific experiments have been reported (Gillett, N. A. *et al.* *J. Natl. Cancer Inst.* *79*: 357, 1987; Hahn F. F. *et al.* *J. Natl. Cancer Inst.* *67*: 917, 1981).

Because of the differences in the solubility of the two radionuclides, different patterns of dose rate to the skeleton occurred in the two life-span studies. The $^{90}SrCl_2$ translocated rapidly to the skeleton, and little was retained in other organs. In the skeleton, the ^{90}Sr was retained with a half-time of over 5 years. Inhaled $^{238}PuO_2$ was retained in the lung for a prolonged time with a half-time of greater than 100 days. The retention pattern was complex because of an increased rate of clearance from the lung beginning at about 100 days after exposure due to breakup and increased solubility of the particles. The increased solubility led, in turn, to increased translocation to the liver and skeleton. The ^{239}Pu was retained in the skeleton with a half-time of over 5 years.

The total numbers of primary bone cancers observed in the two life-span studies are shown in Table 35. These tabulations include multiple, primary bone tumors occurring in a single dog.

Table 35

Primary Bone Tumors in Beagle Dogs Exposed by Inhalation to $^{90}SrCl_2$ or $^{238}PuO_2$

Radionuclide Aerosol	Number of Dogs Exposed	Number of Dogs with Primary Bone Tumors	Number of Primary Bone Tumors	Total Skeletal Dose (Gy): All Exposed Dogs Median (range)	Total Skeletal Dose (Gy): Dogs with Tumors Median (range)	Survival of Dogs with Bone Tumors, Days to Death After Exposure - Median (range)
$^{90}SrCl_2$	66	30	42	60 (4-220)	120 (28-220)	1744 (759-3472)
$^{238}PuO_2$	168	92	122	2.0 (0.1-13)	2.6 (0.3-9.8)	1938 (1125-4815)

The tumor phenotypes are shown in Table 36. The classification scheme follows that of R. R. Pool (In *Tumors of Domestic Animals*, U. of Cal. Press, p. 151, 1990.) Of the ^{90}Sr-induced tumors, 62% were osteosarcomas. Of these osteosarcomas, 37% were osteoblastic, but relatively nonproductive, indicating greater anaplasia.

In contrast, 97% of the ^{238}Pu-induced tumors were osteosarcomas. Two-thirds of these osteosarcomas were osteoblastic, and most were productive, indicating greater differentiation. Another point of contrast was the relatively high percentage of hemangiosarcomas (29%) and telangiectatic osteosarcomas (12%) induced by ^{90}Sr.

*Currently at Genentech, Inc., San Francisco, California

Table 36

Phenotypes of Bone Cancers in Beagle Dogs
That Inhaled $^{90}SrCl_2$ or $^{238}PuO_2$
(% of Total)

Tumor Phenotypes	$^{90}SrCl_2$	$^{238}PuO_2$
Osteosarcomas		
Osteoblastic	23	63
Fibroblastic	2.4	8.2
Chondroblastic	4.8	11
Combined	17	4.9
Telengiectatic	12	4.1
Giant Cell	2.4	0.8
Poorly Differentiated	0	5.7
(TOTAL)	(62)	(98)
Fibrosarcoma	7.1	1.6
Chondrosarcoma	0	0.8
Hemangiosarcoma	29	0
Myxosarcoma	2.4	0
(TOTAL)	(38)	(2)

The distribution of skeletal location of the primary bone tumors is shown in Table 37. In dogs that inhaled $^{90}SrCl_2$, a majority of the tumors occurred in the bones of the skull and pelvis, and in the ribs and scapula. With inhaled $^{238}PuO_2$, a majority of the tumors occurred in the lumbar vertebra, pelvis, and head of the humerus. This distribution of tumors is similar to that shown in studies of these radionuclides administered by other routes, such as injection, that give similar radiation dose patterns to the bone (Gillett, N. A. *et al. Int. J. Radiat. Res. 61(6)*: 821, 1992; Miller, S. C. *et al.* In *Life-span Radiation Effects Studies in Animals*, OSTI, USDOE, p. 286, 1986).

Radiation osteodystrophy was frequently present in the dogs exposed to ^{238}Pu, but seldom in those exposed to ^{90}Sr. In the ^{238}Pu-exposed dogs, radiation osteodystrophy was characterized by osteitis fibrosa, osteosclerosis and, rarely, osteoporosis. Of the 92 dogs with bone tumors, radiation osteodystrophy was detected in 67 (73%). The vertebra and humerus were the bones most frequently involved, but the rib and femur were involved in some cases.

Radiation osteodystrophy in the ^{90}Sr-exposed dogs was characterized by bone infarction, microinfarction cavities, peritrabecular fibrosis, and new bone formation. These lesions were minimal and were observed primarily in rib sections of dogs dying prior to 1300 days after exposure. Of the dogs dying from primary bone tumors, seven (23%) had minimal lesions of radiation osteodystrophy in non-neoplastic bone adjacent to the tumors. Thus, radiation osteodystrophy is probably not a necessary antecedent of bone neoplasia induced by either ^{238}Pu or ^{90}Sr, but may frequently accompany the process.

Table 37

Distribution of Skeletal Location of Primary Bone Tumors
in Beagle Dogs Exposed to $^{90}SrCl_2$ or $^{238}PuO_2$
(% of Total)

Skeletal Location	$^{90}SrCl_2$	$^{238}PuO_2$
Axial		
Skull	26	3.3
Vertebra, Cervical	4.8	6.4
Vertebra, Thoracic	2.4	18
Vertebra, Lumbar	2.4	15
Pelvis (including sacral vertebrae)	14	13
Rib	19	3.3
Sternum	0	3.3
(TOTAL)	(69)	(62)
Appendicular		
Scapula	12	5.6
Humerus	7.1	25
Femur	4.8	5.6
Tibia	7.1	1.6
(TOTAL)	(31)	(38)

The results of these two studies show that the alpha-emitting radionuclide, ^{238}Pu, induced primary bone cancers that were 97% osteosarcomas, primarily of the vertebra, pelvis and humerus. The beta-emitting radionuclide, ^{90}Sr, induced bone cancers that were osteosarcomas, but included a significant number of hemangiosarcomas (29%). The tumors were primarily of the skull, rib, pelvis, and scapula. Radiation osteodystrophy was a frequent finding with ^{238}Pu exposure, but rare with ^{90}Sr exposure. In neither case, however, did radiation osteodystrophy appear necessary for the neoplastic process.

The differences in distribution of bone tumors induced by $^{238}PuO_2$ or $^{90}SrCl_2$ probably relate to the known differences in distribution of the radionuclides in the skeleton and the dose delivered to critical cells. For example, the occurrence of ^{239}Pu-induced skeletal malignancies has been correlated with certain tissue characteristics (Miller, S. C. *et al.*, 1986). Those bones with increased tissue metabolism, as indicated by osteogenic cell numbers, increase the initial uptake of plutonium and the expression of skeletal cancers.

8. Effects of Age and Antigen Exposure Upon *In Vitro* Production of Tumor Necrosis Factor in the Dog

D. R. Davila*, S. E. Jones*, D. E. Bice, and P. J. Haley

Respiratory infections are a primary cause of morbidity and mortality in the elderly (Ishii, T. *et al. Age Ageing 9*: 81, 1980) and may occur because of diminished local immune responses in the lung. The strength of the immune response to antigen in the lung depends upon the intensity of local inflammation (Kaltreider, H. B. *Am. Rev. Respir. Dis. 113*: 347, 1976). In aged dogs, antigen-induced inflammation in the lung is weaker than in younger dogs (Bice, D. E. and B. A. Muggenburg. *Am. Rev. Respir. Dis. 132*: 661, 1985). For this reason, we investigated the effects of age and antigen exposure upon a cell that plays a central role in the pulmonary inflammatory response, namely, the pulmonary alveolar macrophage (PAM). We examined the ability of PAM to secrete tumor necrosis factor-α (TNF-α), a pleiotropic mediator of both the inflammatory and immune responses. The ability of nonactivated macrophages to respond to TNF-inducing stimuli *in vitro* is altered with age in some animal models (Davila, D. R. *et al. FASEB J. 4*: 2906, 1990). We speculated that a change in the ability of PAM to secrete TNF-α with age might also accompany the diminished inflammatory and immune responses to antigen in the lung.

We immunized 11 aged (12-17 years-old) and 12 young (2-3 years-old) dogs with sheep erythrocytes (SRBC) in the left cardiac lung lobe, with keyhole limpet hemocyanin (KLH) in the right cardiac lobe, and with saline in the right intermediate lobe (primary instillation). We used KLH and SRBC so that the effects of both soluble (KLH) and particulate (SRBC) antigen on immune responses could be compared. After 9 days, we lavaged the lung lobes of 5 aged and 6 young dogs and sacrificed the animals for tissue collection. Twenty-one days after primary antigen instillation, we again instilled antigen or saline into the same lung lobes of the remaining 6 aged and 6 young dogs (secondary instillation); these dogs were lavaged and sacrificed 7 days later. We isolated peripheral blood monocytes, splenic macrophages, and PAM from each lung lobe and tested the ability of these cells to secrete TNF-α *in vitro* in response to lipopolysaccharide (LPS) as described (Lorence, R. M. *et al. J. Natl. Cancer Inst. 80*: 1305, 1988). We correlated amounts of canine TNF-α to a standard curve of human recombinant TNF-α, and reported results as units of TNF-α per million macrophages. The Student's *t* test was used to compare aged and young values at either the primary or the secondary timepoints.

Figure 41 shows the units of TNF-α produced by PAM from aged and young dogs at the primary and secondary timepoints. Each panel depicts TNF-α secretion by PAM from a different lung lobe: saline-instilled, KLH-instilled, or SRBC-instilled. At the primary timepoint, instillation of either KLH or SRBC into lung lobes resulted in an overall lowering of *in vitro* TNF-α secretion by PAM from these lobes, when compared to the saline-instilled lobes. In other words, PAM from antigen-instilled lung lobes became tolerant to LPS-induced TNF-α secretion. However, PAM from aged dogs were markedly less tolerant than were PAM from young dogs at the primary timepoint, as indicated by the significantly greater ($p < 0.05$) secretion of TNF-α by aged than by young dog PAM. By the secondary timepoint, PAM from KLH- or SRBC-instilled lobes secreted similar amounts of TNF-α in aged and young dogs. In addition, PAM from saline-instilled lobes also became somewhat hyporesponsive to LPS stimulation *in vitro* after secondary antigen exposure.

The secretion of TNF-α by peripheral blood monocytes and splenic macrophages is presented in Figure 2. This figure shows that while TNF-α secretion by splenic macrophages remained relatively constant with age and antigen exposure, peripheral blood monocyte production of TNF-α fluctuated according to the exposure timepoint, in both aged and young dogs. We have found in our laboratory that normal baseline secretion of TNF-α by peripheral blood monocytes from young dogs is approximately 126 units per million monocytes ($n = 11$). Data in Figure 42 show that the secretion of TNF-α by monocytes from young dogs did not change from this baseline value at the primary timepoint, but increased after secondary antigen exposure.

Our data showed that LPS-induced secretion of TNF-α by monocytes or macrophages *in vitro* depends upon the age of the donor animal, tissue of origin, and primary or secondary antigen exposure. Primary antigen

*Postdoctoral Fellow

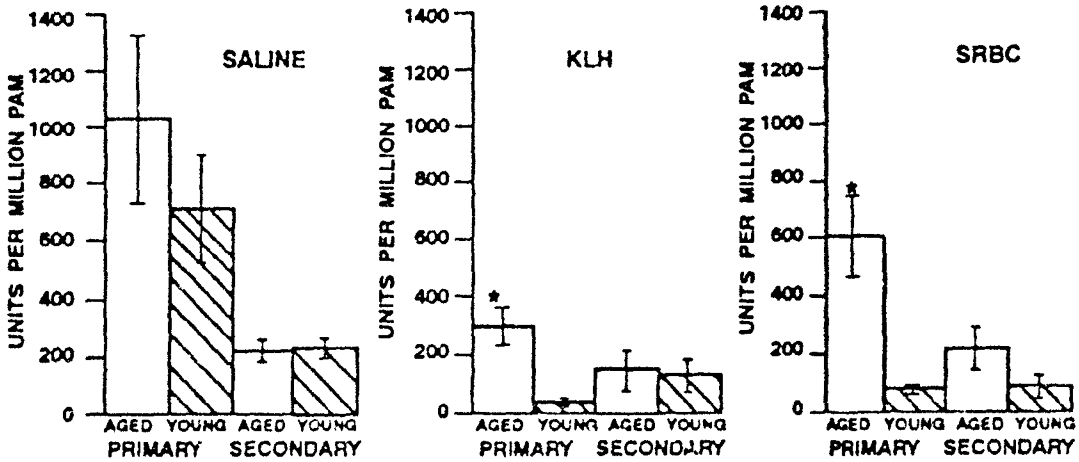

Figure 41. Secretion of TNF-α by PAM from saline-, KLH-, or SRBC-instilled lung lobes of aged and young dogs was measured after primary and secondary antigen exposure. Mean units (± SEM) of TNF-α per million PAM are shown for each group. PAM from aged dogs produced significantly more TNF-α ($p < 0.05$) than young dogs after primary instillation of both KLH and SRBC (*). There were no significant differences ($p > 0.10$) between aged and young dogs at the primary timepoint in saline-instilled lobes, or at the challenge timepoints in saline, KLH, or SRBC-instilled lobes.

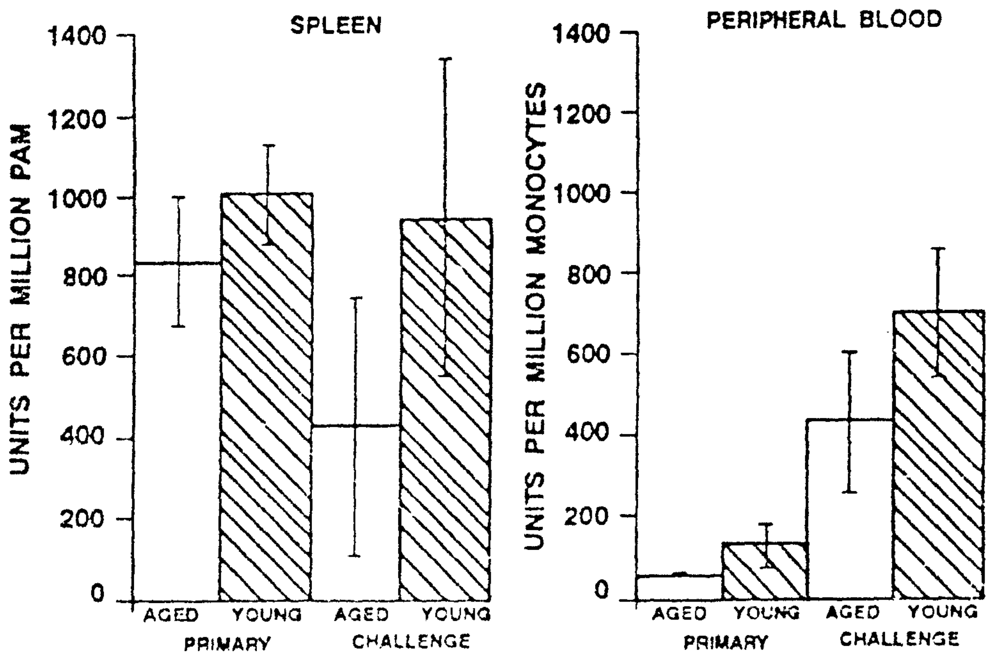

Figure 42. Secretion of TNF-α by peripheral blood monocytes and splenic macrophages from aged and young dogs was measured after primary and secondary antigen exposure. Values represent mean units (± SEM) of TNF-α per million macrophages. There were no significant differences ($p > 0.10$) between aged and young dogs at the primary timepoint, or at the secondary timepoint, in either tissue.

instillation caused a more pronounced refractory state in PAM from young than from aged dogs. This indicated that PAM from aged dogs could not respond to, or did not receive, *in vivo* signals that induced a tolerant state. Work conducted in these same animals showed that primary antibody responses to both KLH and SRBC were very low in aged dogs after primary antigen exposure, but increased dramatically at the secondary timepoint (Jones, S. E. *et al. Mech. Ag. Dev.*, submitted). After secondary antigen exposure, PAM from aged dogs also became refractory. These results link tolerance induction in PAM to the vigor of the antibody response and suggest that the state of activation of PAM plays an important role in the diminished immune response in the lungs of aging dogs.

II. UNIVERSITY OF UTAH LIFE-SPAN STUDIES IN DOGS

A. SPECIFIC PROJECT OBJECTIVES

In 1950, the U.S. Atomic Energy Commission initiated a series of long-term radionuclide toxicity studies in Beagles. At that time, the use of ^{239}Pu for weapons and as a potential source of nuclear fuel was increasing, and plutonium production was a rapidly expanding industry. Because of the known toxicity of radium in humans, the potential toxicity of plutonium was recognized. The original studies at the University of Utah were designed to determine the relative toxicity of ^{239}Pu and ^{226}Ra. Because some human radium toxicity data were available, the animal studies were originally designed to reflect the human experience with ^{226}Ra, providing a basis for extrapolating the long-term toxicity of other internally deposited radionuclides, particularly plutonium from animal studies to humans. As detailed below, the life-span effects of other nuclides were also included in this project.

The Beagle dog was selected for these studies because of concerns that erroneous predictions of human health effects might be made if shorter-lived mammals, such as rodents, were used. These concerns included the possibilities that the radiation-sensitive cancers would only be expressed in animals with longer lifespans and that the target organs might be different in rodents than in humans. Because skeletal tissues were recognized as a primary target organ for radium and plutonium toxicity, further consideration was given to the Beagle because it has skeletal characteristics similar to those of humans that rodents do not have.

The major scientific questions that have been, and continue to be, addressed in the life-span radionuclide studies conducted at the University of Utah include:

1. What are the biological distribution and retention patterns of these nuclides?
2. What types of cancers are produced?
3. What are the dose-effect relationships?
4. Can differences in retention and distribution be used to predict biological response?
5. Does age at exposure influence biological response?
6. What biological factors are important in biological tissues for the expression of radiation effects?
7. What are the target cells for cancer induction?
8. What are the cellular and molecular mechanisms of cancer induction by internally deposited radionuclides in different organs?
9. Can reliable models be developed for predicting risk to humans?

B. EXPERIMENTAL APPROACHES

1. General Procedures

Two general types of studies have been conducted in dogs: life-span studies and sacrifice studies. In life-span studies, the toxicity of selected radionuclides is being studied, and the dogs are allowed to live out their life spans, unless sacrifice is indicated for humane reasons, such as to prevent pain. In sacrifice or test studies, dogs were injected with radionuclides to study the mechanisms of deposition, retention, and specific radionuclide-tissue interactions.

Most of the dogs in the toxicity studies received a single intravenous injection of radionuclide, usually in citrate solution, at 16 to 18-mo old, when their skeletal maturity corresponded to that of an 18-yr old radium dial painter or plutonium worker. In addition, some dogs were injected with ^{239}Pu or ^{226}Ra at 3-mo old (to

represent children) or 5-yr old (to represent middle-aged persons). The dogs were confined in metabolism cages 1 wk before injection and 3 wk after injection (for excreta collection). Exceptions were the dogs receiving one or a series of 10 or 50 injections of ^{224}Ra starting at 21-mo old. These dogs were not confined after injection because the period of injections extended to about 1 yr. In addition, confinement could have interfered with important biological functions.

Each dog in a toxicity study has been followed clinically from the time of injection to death. At death, each dog receives a complete gross necropsy examination, including radiographs of defleshed bones to identify possible tumor sites that are then examined histologically. Histopathological examinations are performed on both the radiation-induced and naturally occurring lesions. These results are then analyzed with regard to the average and local radiation doses received by the affected tissues. Various dose-response relationships are tested for their appropriateness and usefulness in predicting the human health risks for such an exposure.

Because of the maturity of a number of these studies, current emphasis at the University of Utah is directed to activities necessary to complete the studies and publish the results. The radiochemical, metabolic and dosimetric data for both completed and continuing toxicity studies are being collected, collated, and archived. The distribution and local dosimetry of the radionuclides are being studied by using materials collected from both the toxicity and test animals. Average retention, dose, and dose-rate functions for liver and skeleton are being calculated and studied as functions of age at exposure, exposure level, and time after exposure. The occurrence, type, location, and latent period of radiation-induced cancers will be studied both as functions of local or average dose and of dose rate. Dose-response curves are being constructed to extrapolate the health effects seen in these dogs to human health risks.

A critical aspect of this research is the preparation of a complete biological record for each dog and assembly of the observations into a clinical and pathology data base that can be used with the detailed dosimetric data to establish meaningful dose-response relationships for the various radionuclides that have been studied in this program.

The final products of these efforts are publications in the peer-reviewed literature dealing with the observed dose-response relationships and health risk estimates and with a wide range of underlying metabolic, dosimetric, and mechanistic studies. The above efforts are divided between scientists at the University of Utah and the ITRI.

2. Study-Specific Features

This research effort addresses the completion of 14 major life-span studies of dogs given single or multiple intravenous injections of different alpha or beta-emitting radionuclides. The studies included and the time intervals during which dogs were entered on study are described below:

a. ^{239}Pu (Injected from 1952-1974)

Initially, the injected dosages ranged from 0.59 kBq/kg (0.016 μCi/kg) (termed "1-level") from which no harm was predicted, up by a sequence of levels to 106 kBq/kg (2.86 μCi/kg) (termed "5-level") from which severe injury occurred, including hematological damage, liver degeneration and neoplasia, and bone fractures and sarcomas. However, in 1964, when an osteosarcoma occurred at the supposedly safe, 1-level, several lower levels were introduced. The lowest level, 0.022 kBq/kg (0.0006 μCi/kg) (the 0.1-level), resulted in an average skeletal dose of about 0.02 Gy (2 rads) at death. Among the 28 dogs treated at the 0.1 level, one developed a bone sarcoma and another an epidermoid carcinoma of the frontal sinus; both cancers may have been induced by the ^{239}Pu. The selective deposition of ^{239}Pu on bone surfaces makes this radionuclide the most effective of any studied at the Radiobiology Division for inducing bone sarcoma at low doses, per rad of average of skeletal dose. ^{239}Pu also deposits throughout the liver and induces liver cancers.

b. ^{226}Ra (Injected from 1953-1970)

^{226}Ra enabled the relative toxicity of ^{239}Pu vs. ^{226}Ra to be established in Beagle dogs, so that the known toxicity in the U.S. radium dial painters could be used to predict the risk to humans from ^{239}Pu-induced bone sarcoma. ^{226}Ra is chemically similar to calcium and deposits throughout the bone volume, especially in regions

of active growth. The average skeletal dose for each dog was based on the measured retention of ^{226}Ra and progeny. In Beagle dogs, ^{226}Ra at higher dosages produced bone fractures. Bone sarcomas were induced over a wide range of doses. These effects were also seen in the radium dial painters.

c. ^{228}Ra (Injected from 1954-1962)

^{228}Ra was included in these studies because it was received by many of the radium dial painters. In terms of average skeletal dose, ^{228}Ra was about twice as effective as ^{226}Ra for inducing bone sarcoma. The difference may be largely due to the fact that some ^{228}Ra progeny are likely to redeposit on bone surfaces. An important spinoff from the study of ^{228}Ra in dogs was the discovery that the physical half-life of ^{228}Ra is 5.77 $\pm$ 0.02 yr, not 6.7 yr, as was earlier reported by Lise Meitner. Correcting for the proper half-period increased the calculated dose from ^{228}Ra in the dial painters by about a factor of two over earlier estimates.

d. ^{228}Th (Injected from 1954-1963)

^{228}Ra decays to ^{228}Th, and there was early concern that the intestinal absorption of the ^{228}Th in dial painters might be high. Later, it was found that absorption of ^{228}Th from the human GI tract was low, about 0.02% compared to 20% for radium. However, the ^{228}Th toxicity data from Beagle dogs proved very useful for evaluating the risk from radionuclides in the proposed Thorium Breeder Reactor.

e. ^{90}Sr (Injected from 1955-1966)

^{90}Sr toxicity was evaluated because of worldwide concern about radioactive fallout from atmospheric nuclear weapons testing. Few effects were observed at average skeletal doses below 50 Gy (5000 rads), but bone sarcomas occurred frequently at higher doses. Most interesting was the relative ineffectiveness of ^{90}Sr in producing leukemia in adult Beagle dogs. This observation agrees with the low frequency of myeloproliferative syndrome (MPS) observed in Beagle dogs at the University of California, Davis, that were injected with ^{90}Sr as adults. However, a high incidence of MPS was observed in the Davis Beagle dogs exposed to a high dosage of ^{90}Sr administered by feeding from fetal age to adulthood.

f. ^{241}Am (Injected from 1966-1975)

^{241}Am was the first transplutonium radionuclide to be evaluated for toxicity in Beagle dogs at the University of Utah. Because of strong interest in ^{241}Am, especially by Charles Dunham, Head of the AEC's Division of Biology and Medicine, the original test study was expanded into a full-scale toxicity study, with about 12 dogs per dosage level. Control dogs concurrently assigned to the low-level studies of ^{239}Pu and ^{226}Ra were considered suitable as controls for the ^{241}Am studies. In 1975, the number of Beagle dogs at the 1- and 1.7-levels was increased to 26 and 24 dogs, respectively, to study the induction of liver cancer by alpha-emitters more extensively. The liver retains more ^{241}Am than any other monomeric radionuclide studied in Beagle dogs at the University of Utah.

g. ^{249}Cf (Injected from 1971-1974)

^{249}Cf, which emits alpha-particles in 100% of its decays, was the next transplutonium radionuclide to be investigated. Fortuitously, tracer amounts of beta-emitting ^{249}Bk were present with the alpha-emitting ^{249}Cf, making it possible to establish that the microscopic depositions of Bk and Cf were similar.

h. ^{252}Cf (Injected from 1971-1973)

^{252}Cf releases half of its decay energy in alpha-particles and half in extremely densely ionizing fission fragments. The ^{252}Cf and ^{249}Cf studies were run simultaneously in Beagle dogs and in mice. In the mouse studies, the fission fragments of these radionuclides were much less effective than alpha particles per Gy of average skeletal dose for inducing bone sarcoma. It is already obvious that the fission fragment dose is much less effective than the alpha-particle dose for inducing bone sarcoma in Beagle dogs. This information is significant to the astronaut who may receive appreciable radiation dose to bone from extremely densely ionizing cosmic rays.

i. ^{253}Es (Injected from 1973-1974)

Einsteinium (element 99) was the highest element on the periodic chart to be investigated for radionuclide toxicity in Beagle dogs. Einsteinium appeared to resemble Cf most closely in its excretion, retention and tissue distribution. No bone sarcomas occurred among the five toxicity-study Beagle dogs injected with ^{253}Es, excluding the one dog that subsequently received a large dose of ^{249}Cf. This suggests that ^{253}Es, which delivers its dose with a 20-day half-life, is not appreciably more toxic than the other transplutonium elements studied.

j. ^{224}Ra (Injected from 1977-1979)

Toxicity studies with ^{224}Ra ($T_{1/2}$ = 3.62 days) were undertaken to understand the modifying effect of protraction on the dose-response of ^{224}Ra observed in German ankylosing spondylitis patients. Four graded-dose levels were administered over three injection spans. Groups 1-2 received their ^{224}Ra in 50 weekly fractions to correspond to the average injection span in German children; Groups 41-52 received a single injection, and Groups 81-92 received 10 weekly injections to correspond to the more recent treatment used in Germany for ankylosing spondylitis. Most of the ^{224}Ra given the Beagle dogs was prepared by Amersham-Buchler in Germany, which also prepared the ^{224}Ra for the German ankylosing spondylitis patients. The studies of ^{224}Ra in Beagle dogs are among the most important with respect to understanding the mechanisms of alpha-particle-induced cancer. The short half-life of ^{224}Ra causes some of it to decay on bone surfaces and some to decay within the bone volume, giving a local distribution of dose in bone somewhat similar to that from ^{239}Pu. In the Beagle dogs receiving 2.8 Gy (280 rad) from ^{224}Ra injections protracted over 50 wk, the bone sarcoma appearance times and incidences were similar to those observed from the same skeletal dose from ^{239}Pu. It remains to be seen, however, what the effectiveness of ^{224}Ra will be at lower doses and shorter protraction times. The ^{224}Ra study, being the most recent, has the largest number of living dogs.

k. Toxicity Studies in Immature and Aged Beagle Dogs

Because of concern about the effects of radionuclides on members of the general public with widely different ages, the studies in Beagle dogs were expanded to include administration at 3-months old (to represent children) and 5-years old (to represent middle-aged adults). ^{239}Pu was selected as the bone-surface-seeking radionuclide of greatest concern, while ^{226}Ra was chosen to represent the bone-volume seeking radionuclides. Much attention has been given to the effect of changing distribution of radioactivity with age in these dogs and to the associated biological effects.

C. CURRENT STATUS OF THE UTAH STUDIES

1. General Overview

The current status of the 14 life-span radionuclide toxicity studies initiated at the University of Utah is given in Table 38. On September 15, 1987, all living dogs in these studies, 157, were moved to the ITRI colony for continuation of their care and biomedical evaluation for the remainder of their lives. Between September 15 1987 and September 30, 1990, 96 of these transferred dogs died. During the past fiscal year, an additional 26 dogs died, resulting in a population of 39 living dogs on September 30, 1991. These deaths reflect the maturity of these studies and the dogs in them at the time of transfer. The 39 living dogs are about 3% of the total population of dogs entered into these studies. These living dogs are part of the populations in three studies, the ^{224}Ra study in young adult dogs and the studies of ^{226}Ra or ^{239}Pu in immature dogs.

The research currently devoted to the Utah efforts fall into three main areas: 1) continuation of the care and study of dogs still alive in these six studies, 2) detailed dosimetric studies, at the organ and local levels, of these injected radionuclides and the factors that influence these dose patterns and 3) completion of final reviews of biological materials and data, compilations and analysis of data, and preparation of final study reports for publication in the open, scientific literature. Section IV.C. provides a listing of previous document reports on these studies, summaries of current research highlights and a discussion of current, and future wrapup activities for these studies.

Table 38

Current Status of Life-Span Radionuclide Toxicology Studies in Beagle Dogs Initiated at the University of Utah and Being Continued at the Inhalation Toxicology Research Institute (9/30/91)

Age at Injection	Radionuclide Injected	Injection Year	Dogs Entered in Study	Dogs Transferred 9/15/87	Number Alive 9/30/90	FY-1991 Deaths	Number Alive 9/30/91
16-18 mo (young adult)	^{239}Pu	1952-1974	286	11	1	1	0
	^{226}Ra	1953-1970	164	0	0	0	0
	^{228}Ra	1954-1962	89	0	0	0	0
	^{228}Th	1954-1963	94	0	0	0	0
	^{90}Sr	1955-1966	96	0	0	0	0
	^{241}Am	1966-1975	117	8	0	0	0
	^{249}Cf	1971-1974	36	5	0	0	0
	^{252}Cf	1971-1973	36	3	0	0	0
	^{253}Es	1973-1974	6	0	0	0	0
	^{224}Ra	1977-1979	128	78	36	14	22
3 mo. (immature)	^{239}Pu	1972-1978	75	24	13	4	9
	^{226}Ra	1975-1978	54	24	11	3	8
5 yr. (aged)	^{239}Pu	1975-1978	34	3	0	0	0
	^{226}Ra	1975-1980	34	1	0	0	0
		Total	1249	157	61	22	39

D. COMPLETION ACTIVITIES FOR THE UTAH STUDIES

Because of the joint ITRI/Utah involvement in the completion of Utah studies, lead roles have been assigned for the various studies as shown in Table 39. In the studies in which most or all of the dogs have already died, Utah has the lead role, whereas ITRI will assume the lead role for those studies that will be completed later. Present wrapup emphasis is directed toward the studies in which young adult dogs were injected with ^{226}Ra or ^{239}Pu. The strategy for the analysis of each study includes a thorough review of all records including pathology, clinical, radiographic, dosimetric, radiochemical, and metabolic. For each study, a series of milestones has been established and specific oversight assignments given to specific investigators. The primary goal is to produce a document that summarizes all data in the study. In addition, numerous smaller, more specific papers are being published as the work progresses.

An example of the working "Milestone Schedule" for the Radium Young-Adult study is shown in Table 40 and its detailed footnotes. A similar schedule has been developed for the ^{239}Pu study as shown in Table 41. The appended footnotes explain some of the analyses being done for this wrap-up effort. The same types of approaches will be used in other study completion efforts to follow as appropriate.

Table 39

Currently Planned Division of Efforts to Complete and Publish the Lifetime Toxicity Studies in Beagle Dogs from the University of Utah

Radionuclide	Age Category	Lead Institution
^{226}Ra	Young Adult	U. of Utah
^{90}Sr	Young Adult	U. of Utah
^{239}Pu	Young Adult	U. of Utah
^{228}Ra	Young Adult	U. of Utah
^{228}Th	Young Adult	U. of Utah
^{241}Am	Young Adult	U. of Utah/ITRI
^{249}Cf	Young Adult	U. of Utah/ITRI
^{252}Cf	Young Adult	U. of Utah/ITRI
^{253}Es	Young Adult	U. of Utah/ITRI
^{226}Ra	Aged	U. of Utah/ITRI
^{239}Pu	Aged	U. of Utah/ITRI
^{226}Ra	Immature	ITRI
^{239}Pu	Immature	ITRI
^{224}Ra	Young Adult	ITRI

Table 40

Milestone Schedule for Completion of
Summary Report on ^{226}Ra Young Adult Dog Longevity Study
(September 30, 1991)

Topic	Status
Historical review	Complete
Experimental designs	Complete
Histopathology, SNOMED [a]	Complete
Expanded controls [b], SNOMED	Complete
Metabolism, retention	
General [c]	Complete
Model developed from new data from individual bones and plasma	Pending
Gross dosimetry [e]	Complete
Survival analyses [f]	
Low doses	Complete
High doses	Pending
Dose-response (bone tumor incidence) [g]	Complete
Hematopoietic, lymphoid response	
Summary of old data [h]	Complete
Final tumor data [i]	Complete
Other soft tissues [j]	Pending
Skeletal tissues	
Skeletal tumor, verification [i]	Complete
Skeletal tumor, location [i]	Complete
Radiography [k]	Pending
Histology, microradiography [l]	Pending
Fractures [m]	Complete
Tooth loss [n]	Complete
Local dosimetry [o]	Pending
Jaw syndrome [n]	Complete
Discussion and summary [p]	Pending
Review and submission [q]	Pending

[a] SNOMED: Systemized Nomenclature of Medicine, College of American Pathologists. This is the standardized database for all histopathology. This database is on a Digital microVAX system and is transferred to the National Radiobiology Archive.

[b] Expanded controls: In addition to the control dogs assigned to this study (R0.0), controls from other studies have been included in many of the analyses to increase the validity of comparing radiation and nonradiation effects. These controls are included in all models and statistical comparisons.

Table 40

[c] General metabolism: The metabolism of radium (and some other nuclides) is determined from the "test" animals and not the "chronic toxicity" animals. There were serial sacrifice studies done for early distribution, localization, and dosimetric studies.

[d] Plasma: Results from a shorter term metabolism study are pending. These data will allow more precise determinations of blood nuclide levels and improvements in present metabolic models.

[e] Gross dosimetry: Average skeletal dose calculated for each dog.

[f] Survival analyses: Presently, Cox proportional hazard models are being applied for survival analyses to the different dose groups. The statistical models are complicated by a number of factors including the need to censor animals with epilepsy, and use of control and treated animals over 3 decades with improved life expectancy due to improved veterinary practices. Initial analyses with low dose groups have been published. Analyses are continuing in higher dose groups.

[g] Tumor incidence: Emphasis is on skeletal tumors. Only those tumors that were verified histologically are included in these analyses. In some cases, the histological diagnosis may be disputed. The location of the tumors is documented from clinical, necropsy and radiographic records. The location of the tumors and the apparent type of tissue or origin (*e.g.*, cancellous or cortical bone) become very important parts of the skeletal dosimetry studies.

[h] Old hematology data: Due to the bone-seeking nature of these isotopes, it was originally believed that hemic tumors would be an important consequence of radionuclide exposure. This was not observed in the human or the early animal studies, and a programmatic decision was made by the A.E.C. to end the detailed hematopoietic studies in the early 1970's. We are now attempting to reconstruct the data that were collected to that date. Unfortunately, there was little hematological information obtained after that date.

[i] Final hematological tumor data: The final incidence of hemic and lymphoid tumors is verified.

[j] Other soft tissues: Although not historically emphasized in these studies, all tissues are being reviewed, and the data tabulated. Particular emphasis has been placed on the liver, mammary glands, kidney, thyroid, and eyes. It has been noted, for example, that the dial painters appear to have a higher incidence of mammary tumors (perhaps from external and not internal exposures).

[k] Radiography: Radiographic summaries are prepared on each dog and entered into the clinical record on the database. Attempts are also being made to quantify some dose-response relationships in the radiographs. This effort is complicated by the fact that there are substantial changes in the skeletal tissues that may be attributable to aging seen in many, but not all dogs. Presently a descriptive summary is being prepared.

[l] Histology and microradiography: A summary of the histology (independent of skeletal tumors) and microradiographic changes is being prepared.

[m] Fractures: Increased fracture occurrence is a known consequence of Ra exposure. The incidence and location of fractures has been updated and summarized.

[n] Tooth loss and periodontal tissue changes are also known to occur with Ra exposure. The loss of teeth and the rate of tooth loss have been determined and are correlated with increasing dosages. The changes in oral tissues (jaw syndrome) are documented and summarized.

[o] Local, cellular dosimetry: This productive effort involves collaboration with Dr. Erich Polig, Karlsruhe, Germany. Dr. Polig spent about 4.5 years in our laboratory and developed and applied an automated scanning microphotometer system for the radium dosimetry studies. From these data and companion biology studies, extensive cellular dose models have been constructed and published.

[p] Summary: The summary will be considered complete when the items identified above are finished, with the exception of the local dosimetry program which will continue.

[q] Publications are submitted to peer-reviewed journals. In addition to the "Summary Paper(s)", a number of articles dealing with specific scientific issues will continue to be published in appropriate journals.

Table 41

Milestone Schedule for Completion of
Summary Report on ^{239}Pu Young Adult Dog Longevity Study
(September 30, 1991)

Topic	Status
Historical review	Pending
Experimental designs	Pending
Histopathology, SNOMED	
Clinical summaries	Complete
Radiographic summaries	Pending
Metabolism	
General	Complete
Short term studies	Pending
Gross dosimetry	Complete
Soft tissues - dosimetry	Complete
Liver, kidney, spleen	Pending
Other soft tissues	
Dose-response	
Tumor incidence	
Skeletal	Pending
Soft tissue	Pending
Survival analyses	
Low doses	Complete
Higher doses	Pending
Hematology	Pending
Skeletal tissues	
Skeletal tumor,	Complete
Skeletal tumor, location	Complete
Radiography	Pending
Histology	Pending
Microradiography	Pending
Autoradiography	Pending
Fractures	Pending
Jaw	Pending
Local dosimetry	Pending
Soft tissues	
Liver	Complete
Gonad	Complete
Other	Pending

E. RECENT RESEARCH ACCOMPLISHMENTS

1. Eye Tumors and Other Lesions Among Beagle Dogs Given ^{90}Sr OR ^{226}Ra*

R. D. Lloyd, G. N. Taylor, W. Angus, F. W. Bruenger, and S. C. Miller

It is well-known that dogs and other animal species injected with radium (Ra) (or with other radionuclides that have Ra isotopes as progeny) exhibit radiation effects in the eye, including pigmentary changes and tumors, especially intraocular melanomas (Taylor, G. N. *et al. Radiat. Res. 51*: 361, 1972; Taylor, G. N. *et al.* In *Risks from Radium and Thorotrast*, BIR Report 21, British Institute of Radiology, London, p. 86, 1989). Cumulative radiation dose to the eye was similar to the cumulative dose to their respective skeletons in our Ra-exposed Beagle dogs. Intraocular melanomas have also been reported as resulting from the ^{90}Y beta radiation originating in bony structures near the eye of Beagle dogs containing skeletal deposits of ^{90}Sr (White, R.G. *et al.* In *Joint Bone Radiobiology Workshop*, USDOE Report UCD-472, p. 17, 1991), with the cumulative dose to the eye averaging up to about 20% of the respective cumulative skeletal doses. These results prompted us to examine the data from the Utah Beagle dog colony to determine whether a similar effect on eye tumor occurrence could be discovered among our dogs given ^{90}Sr. Corresponding data for our 120 life-span dogs given 0.2-440 kBq/kg of ^{226}Ra (Taylor G. N. *et al.* 1989) and 133 comparable control dogs were also reviewed for comparison.

Eighty-six young adult dogs, aged 14 to 20 mo, were given a single injection of ^{90}Sr at one of seven dose levels ranging from about 2.2 to 3700 kBq/kg body mass and allowed to live out their life spans. Dogs were observed daily, and a complete examination was performed at least semi-annually or when indicated by something seen in the daily observation. Soft tissue tumors were removed surgically when possible, but neither chemotherapy nor radiotherapy was given. Skeletal tumors were not treated. A complete necropsy was performed when animals died or were euthanized if life could no longer be supported humanely. Histological examination was performed on all soft tissue lesions sampled at biopsy (or enucleation, for the eye) or at necropsy, and lesions were classified according to standard criteria and standard nomenclature as found in SNOMED ([R. A. Côtè, ed.], Systematized Nomenclature of Medicine, Vol. 1, Second Edition, Skokie, IL: College of American Pathologists; 1984). In 1984 it was agreed that SNOMED and its extension to the Beagle dog (SNODOG, Watson, C. R., Battelle PNL, Richland, WA, personal communication) should form the basis for standard classification of lesions for the Beagle dog laboratories in the U.S. DOE system.

Tables 42 and 43 exhibit the results of our analyses of the reported eye pathology for dogs in our colony given ^{90}Sr or ^{226}Ra, and for the controls. It is not obvious from these data that tumors of the eye might have been induced by the ^{90}Sr + ^{90}Y in the eye or by the ^{90}Sr + ^{90}Y in adjacent bone, since no eye tumors were detected among our dogs given ^{90}Sr + ^{90}Y.

Concentration of injected Ra or radiostrontium in the eyes of our dogs was reported many years ago (Stover, B. J. *et al.* In *Some Aspects of Internal Irradiation*, Pergamon Press, Oxford, p. 7, 1962). For times after injection ranging from 12 to 968 days (three dogs), the concentration of injected Ra averaged 1.25×10^{-3}% of injected activity/g of eye and ranged between 2.5×10^{-5} and 3.7×10^{-3}%/g. Corresponding data for ^{90}Sr in eyes ranged from 4.9×10^{-6} %/g to 3.0×10^{-4}%/g for times after injection of 8 to 960 days (three dogs) with an average of 1.75×10^{-4}%/g, only about 5 to 12 times lower than for ^{226}Ra. Any comparison of dose-rates from incorporated ^{226}Ra + progeny and incorporated ^{90}Sr + ^{90}Y should consider the differences in both radiation quality and radiation energy absorbed per radioactive disintegration (several MeV of short range alpha rays for Ra + progeny and less than 1 MeV of longer range beta rays for ^{90}Sr + ^{90}Y, with a substantial fraction of the beta-ray energy from the Sr + Y escaping the eye).

Tables 42 and 43 indicate that there are a few lesions for which the occurrence in dogs given Ra was substantially higher than in either the control dogs (c) or the animals given radiostrontium (Sr). These include hyperpigmentation + melanosis + hyperplasia (10.5% c, 9% Sr, 42.5% Ra), melanoma (1% c, 0% Sr, 12% Ra), and (with less dissimilarity among groups) fibrosis (1% c & Sr, 5% Ra), hypo- or de-pigmentation (1% c,

*Radiobiology Division, University of Utah School of Medicine, Salt Lake City, Utah

Table 42

Eye lesions among dogs from our colony given ^{90}Sr or ^{226}Ra as young adults compared with control dogs given no radioactivity. Lesions of the eyelid or conjunctiva (including tarsal and lachrymal glands) are excluded from this list. Numerals in parentheses indicate the total number of lesions, while those not in parentheses within the body of the table indicate the total number of dogs with the lesion. Numerals in the superscripts show the numbers of lesions in each structure. Only those lesions shown in ***italic bold type*** were considered by our pathologists to be tumors.

Lesion	Controls (133 dogs)	^{226}Ra (120 dogs)	^{90}Sr (86 dogs)
Adhesion	1 (2)[d,g]	1[e]	0
Atrophy	0	2[i]	0
Cataract	1[i]	1[h]	0
Degeneration	2[j]	8 (9)[6i,2h,e]	3[i]
Fibrosis	1 (3)[c,d,f]	6[b,d,4e]	1[d]
Hemorrhage, Hemosiderosis	1[j]	1 (2)[c]	2[i]
Hyperpigmentation + Melanosis + Hyperplasia	14 (19)[d,12c,6f]	51(89)[b,52c,5d,24f,6e,j]	8[d,6c,f]
Hypo-or depigmentation	1[j]	7[2b,2f,3e]	0
Melanoma	2[c]	14 (17)[13c,e,3f]	0
Necrosis	2[d,i]	2[h,i]	0
Proliferation	0	1[k]	0
Retinal detachment	1[h]	0	0
Vascularization	2[d]	6[d]	3[d]
Others:			
Collagen condensation	0	1[b]	0
Collapse, chronic	0	1[e]	0
Congestion	0	1[b]	0
Cytoplastic vacuolization	6[h]	2[h]	1[h]
Dilatation	1[i]	0	0
Edema	0	1[i]	0
Infiltration + Inflammation + Leukocytosis + Pannus	5 (6)[a,2c,2d,j]	6[b,3d,e,i]	3[b,d,f]
Involution	0	1 (2)[c,f]	0
Rupture	1[a]	0	0
Ulcer	1[d]	0	0
Total of "Others"	14	13	4

[a]Anterior chamber
[b]Choroid
[c]Ciliary body
[d]Cornea
[e]Eye, not otherwise specified
[f]Iris
[g]Iris and ciliary body
[h]Lens
[i]Retina
[j]Vitrous body
[k]Uvea

Table 43

Percentage occurrence of eye lesions among Beagle dogs from our colony given ^{90}Sr or ^{226}Ra as young adults compared with control dogs given no radioactivity, based upon data in Table 42 and the total number of dogs in each group (see caution in text). Only those lesions shown in ***italic bold type*** were considered by our pathologists to be tumors. Percentages shown in bold type are probably[a] or possibly[b] different between groups.

Lesion	Percent occurrence[c]		
	Controls (133 dogs)	^{226}Ra (120 dogs)	^{90}Sr (86 dogs)
Adhesion	0.75	0.83	0
Atrophy	0	1.67	0
Cataract	0.75	0.83	0
Degeneration	1.50	**6.67**[b]	3.49
Fibrosis	0.75	**5.00**[b]	1.16
Hemorrhage, Hemosiderosis	0.75	0.83	2.33
Hyperpigmentation + Melanosis + Hyperplasia	10.5	**42.5**[a]	9.30
Hypo-or depigmentation	0.75	**5.83**[b]	0
Melanoma	0.75	**11.7**[a]	0
Necrosis	1.50	1.67	0
Proliferation	0	0.83	0
Retinal detachment	0.75	0	0
Vascularization	1.50	5.00	3.49
Others:			
Collagen condensation	0	0.83	0
Collapse, chronic	0	0.83	0
Congestion	0	0.83	0
Cytoplastic vacuolization	4.51	1.67	1.16
Dilatation	0.75	0	0
Edema	0	0.83	0
Infiltration + Inflammation + Leukocytosis + Pannus	3.76	5.00	3.49
Involution	0	0.83	0
Rupture	0.75	0	0
Ulcer	0.75	0	0
Total of "Others"	10.5	10.8	4.65

[a]Probably different from other groups, $p < 0.05$.

[b]Possibly different from other groups.

[c]Not all eyes of the dogs shown in this table were sectioned and prepared for histological examination. Only eyes with grossly apparent lesions were evaluated. Few, if any, eye tumors probably were overlooked, but an unknown proportion of other lesions may have been missed. Consequently, one should use caution in calculating the fraction of dogs with eye lesions based upon their numbers and the number of dogs shown above. The percentage of occurrence appearing in this table should not be considered as incidence values.

0% Sr, 6% Ra), and degeneration (1.5% c, 3% Sr, 7% Ra). In general, there were too few lesions in most categories to show significant differences between groups. The "Other" category seems not to be substantially dissimilar among all three groups, however.

Virtually all of the long-lived dogs given ^{226}Ra exhibited melanocyte hyperplasia, hyperpigmentation and/ or melanosis in the eye. No eye melanomas classified specifically as benign were reported in any animal summarized in Table 1. However, White R. G. *et al.* (1991) reported that of the 14 eye melanomas identified among their dogs given ^{226}Ra (11 cases) or ^{90}Sr (three cases), only four were classified as malignant, all of these occurring among their Ra dogs. Our criteria for classification of eye melanomas have been published (Taylor G. N. *et al.* 1989): "The distinction between extensive pigmentary hyperplasia and neoplasia was sometimes indistinct. The degrees of local destruction and scleral invasion were two criteria that were arbitrarily used in classifying some of the lesions as hyperplastic or neoplastic." All eye tumors classified as "melanomas" and exhibited in Table 1 had some characteristics of malignancy (19/19 = 100%), whereas the data of White R. G. *et al.* (1991) indicate that only 4/14 = 29% of their lesions classified as eye melanomas were malignant. Some of their criteria for malignancy appear to be included in the statement made in their paper that, "Three of those four [malignant eye melanomas] resulted in widespread metastasis, emanating from this primary ocular site, and in each case melanoma was the cause of death." Very few of the malignant melanomas shown in Table 1 resulted in metastasis, but all were found to be invasive or to have other characteristics of malignant tumors. Diters R. W. *et al.* (*Vet. Pathol. 20*: 379; 1983) caution, however, that, "...We do not advocate classification of uveal melanomas as benign or malignant at this time because too few follow-up studies have been done...", but they also maintain that, "...Ultrastructurally, the finding of premelanosomes or mature, non-phagocytized melanosomes indicates that these are tumor cells and not macrophages..."**

White R. G. *et al.* (1991) reported the occurrence in their animals of some nonmelanoma eye tumors. There was one benign meningioma, derived from the optic nerve, and one benign ciliary body tumor. We observed neither tumor type among dogs shown in Table 42.

It should be noted that not all eyes of the 133 control dogs, the 120 Ra dogs or the 86 Sr dogs were sectioned and prepared for histological examination. Only eyes with grossly apparent lesions were evaluated. Few, if any, eye tumors probably were overlooked, but an unknown proportion of other lesions may have been missed. Consequently, one should use caution in calculating (Table 2) the fraction of dogs with eye lesions based upon their numbers and the number of dogs shown in the column headings in Tables 42 and 43.

Our conclusions from the foregoing are: (1) The data from the Utah dog colony indicate that neither benign nor malignant intraocular tumors in excess of the rate for our control animals appeared as a result of radiation from incorporated $^{90}Sr + ^{90}Y$. (2) It is unequivocal that melanomas are produced by injected ^{226}Ra. (3) Intraocular neoplasia, hyperplasia, hyperpigmentation and melanosis in the eye do occur in the absence of injected radioactivity such as in our control dogs. (4) Tumor experience as currently reported for animals from different dog colonies may not be directly comparable because of differing rates of discovery, nonuniform nomenclature and varying criteria for classification of lesions with their discordant interpretation by different pathologists, a situation which may or may not be resolved in the future by the adoption of uniform paradigmatic standards and nomenclature.

**If we had classified 1/3 of the 116 hyperplasias + hyperpigmentation + melanoses shown in Table 1 as benign melanomas (39) and the 19 melanomas as malignant, then there would have been 19/58 = 33% malignancies, much closer to the malignant-to-total proportion reported by White *et al.* of 29% than to the estimate made from our melanoma data shown in Table 1 of 100%. Other proportions than 1/3 of the hyperplasias + hyperpigmentation + melanoses might be appropriate as being classified by other pathologists as "benign melanomas."

2. Mammary Tumors Among Beagles Injected With ^{226}Ra*

F. W. Bruenger, R. D. Lloyd, G. N. Taylor, W. Angus, and S. C. Miller

An excess of mammary cancer has been observed among women exposed occupationally during young adulthood to $^{226+228}Ra$ and among women who had received ^{224}Ra therapeutically before puberty (Spiess, H. *et al.* In *Risks from Radium and Thorotrast*, BIR Report 21, British Institute of Radiology, London, p. 7, 1989; Rowland, R. E. *et al.* In BIR Report 21, p. 67, 1989). It is unknown whether the increased tumor occurrence was due to contamination with either ^{224}Ra or $^{226+228}Ra$ and/or their progeny as internal radiation sources, gamma radiation from the $^{226+228}Ra$ stored in the workplace, diagnostic X-ray or fluoroscopy given to young women with tuberculosis treated with ^{224}Ra, other possible carcinogens (eosin or platinum) in some therapeutic injections of ^{224}Ra, or from a combination of factors. There are numerous reports that describe studies concerned with determining the radiation-induced risk of mammary tumors in women (e.g., Rowland R. E. *et al.* 1989; Spiess H. *et al.* 1989; Boice, J. D. *et al. Radiat. Res. 125*: 214, 1991; Tokunaga, M. *et al. Radiat. Res. 112*: 243, 1987; Hildreth, N. G. *et al. N. Engl. J. Med. 321*:1281, 1989). Because of the human experience with mammary cancer in women contaminated with Ra, data from animal experiments constitute a valuable source of additional information that may ultimately provide a better understanding of radiation-induced mammary tumors.

Existing records of tumor occurrence in soft tissues in the University of Utah dog colony among 61 purebred Beagle dogs injected as young adult females with ^{226}Ra and 65 female control dogs, all maintained for life-span observation, provided the opportunity for us to examine these data for evidence of an effect of Ra exposure on mammary tumor appearance. The animals were subjects in a study of Ra-induced bone cancer. A total of 130 primary mammary tumors (66 of them malignant) occurred among 35 of 61 female young adult dogs who were injected with ^{226}Ra in one of eight dose levels ranging from 0.2 to 440 kBq/kg body mass, while a total of 159 mammary tumors (56 of them malignant) were seen among 45 of 65 female control dogs not given any radioactivity. All mammary tumors were removed surgically at diagnosis if possible. Dogs living to the minimum age for diagnosis with a mammary tumor of 4.42 y included 57 given Ra and 63 controls. The control animals were introduced into the experiment at a comparable age and were treated exactly the same as the Ra dogs, except that they received an injection of only the sodium citrate-citric acid buffer without added radioactivity at the time they entered the experiment instead of the same buffer containing Ra.

Several aspects of the frequency and time of occurrence of the mammary tumors in control dogs and Ra-injected dogs were analyzed (Cox, D. R. *Statis. Soc. B. 34*: 187, 1972; Kalbfleish, J. D. and R. L. Prentice. In *The Statistical Analysis of Failure Time Data*, Wiley, New York, 1980; Hopkins, A. In *BMDP Statistical Software Manual* (W. Dixon, ed.) Univ. of California Press, Berkeley, p. 719, 1988). Three situations were considered: (1) occurrence of only the first tumor in each dog; (2) occurrence of all mammary tumors, including each successive tumor but excluding those that were identical in type and location for the same dog (which were considered recurrences); and (3) occurrence of successive tumors, but regarding simultaneously removed tumors at different locations or of different types as a single failure (one failure per date). Malignant mammary tumors were also considered separately within the three categories specified above.

Cox regression showed no significant difference in time of first tumor appearance between Ra-injected dogs and controls, either for all tumors ($p = 0.48$) or for only malignant tumors ($p = 0.21$). Kaplan-Meier weighted cumulative tumor rates of all combined malignant and benign mammary tumors (except recurrence at the same location) and of successively removed tumors (taking simultaneously removed mammary tumors as a single failure) indicated a significant shift for Ra dogs to shorter times and higher magnitudes ($p = 0.004$, $p = 0.007$, respectively). The same trend was evident for malignant tumors only ($p = 0.001$ and $p = 0.022$, respectively). Median times of tumor removal or death with mammary tumor indicated that the age at mammary tumor appearance was less in Ra dogs compared to controls ($p < 0.05$) except for the appearance of only the first mammary tumor. This was the case for all tumors taken together and for malignant tumors only. Dogs given > 5 kBq/kg were younger at time of tumor appearance than dogs given < 5 kBq/kg ($p < 0.05$) except for malignant tumors only.

*Radiobiology Division, University of Utah School of Medicine, Salt Lake City, Utah

Other soft tissue cancers and skeletal malignancies were important competing causes of death among the dogs given Ra, illustrated by the observation that no malignant and only two benign mammary tumors were seen in dogs given 31 to 440 kBq/kg. Other soft tissue cancers were important competing causes of death among controls, also perhaps reducing the expression of mammary tumor occurrence. At least some of the standard biostatistical tests adjust the analysis for the effects of competing risks.

Autoradiography of mammary tissue from our tissue archives that was obtained soon after Ra injection revealed that some ^{226}Ra originally had been deposited therein (Fig. 43). Gamma-ray spectroscopy indicated that the radon progeny activity observed in the intact tissue blocks was probably supported by ^{226}Ra and that no ^{210}Pb could be detected in excess of the amount to be expected from the spectrum of ^{226}Ra + radon daughters that was found. Thus, the radiation dose received was derived from the injected ^{226}Ra and its progeny.

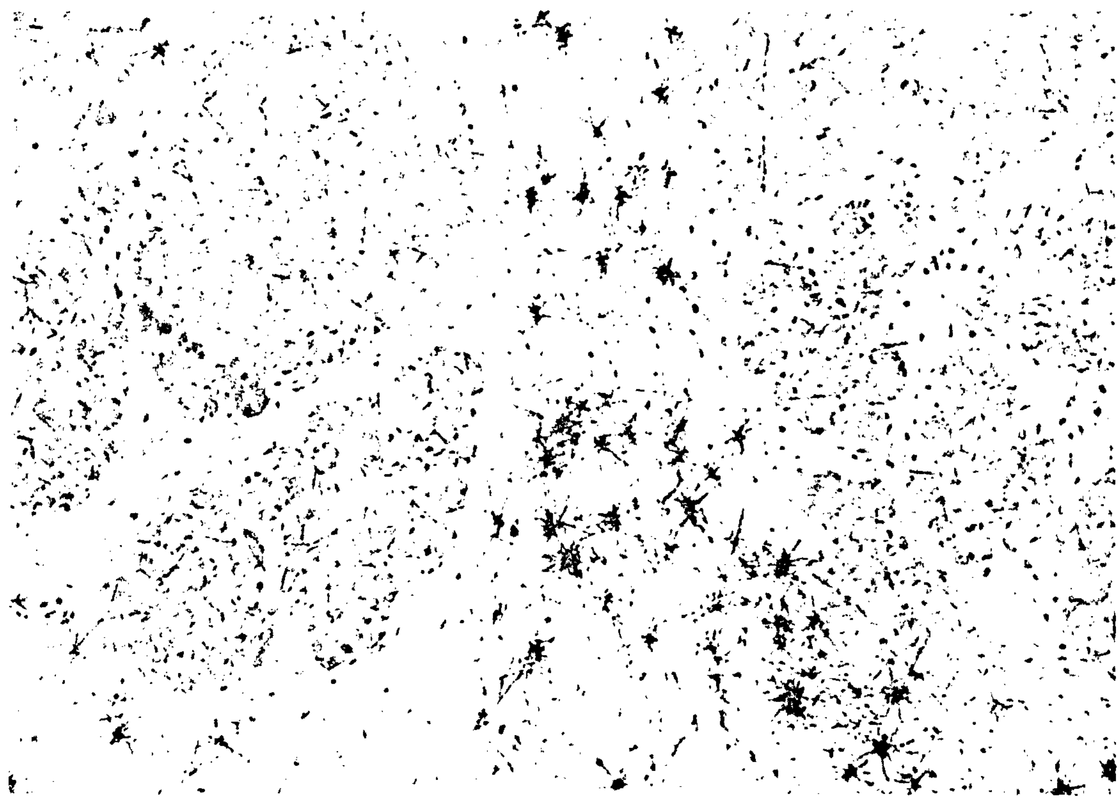

Figure 43. Autoradiograph of mammary tissue from a nonpregnant female Beagle dog (T49R5) during the early metestrus phase of the estrous cycle and at 490 days of age. The animal was sacrificed 5 days after the injection of 279 kBq ^{226}Ra per kg body mass. Lobulation is moderately defined; most alveoli have small lumens; and mitotic figures are fairly abundant. The alpha activity is derived principally from the perilobular connective tissue and to a lesser extent from the intralobular stroma. Deposition in the parenchyma appears to be minimal. However, irradiation of the glandular elements from the connective tissue activity is apparent. A precise deposition site in the stroma is not discernible, but in other sections, some of the focal activity was associated with cytoplasmic, hemosiderin-like pigment in macrophages. Gamma-ray spectroscopy indicated that this activity was ^{226}Ra + progeny rather than ^{210}Pb + progeny. Hematoxylin and eosin stain, 14 day exposure, 190X.

The possible influence of diagnostic X-ray exposure on the expression of mammary tumors was also investigated (Table 44). The total number of X-ray examinations per dog depended somewhat upon the length of each dog's life span and upon its unique clinical history. The average numbers of radiographic examinations per dog among the various groups of dogs were significantly different only for the comparison of controls vs. the low-level Ra group (< 5 kBq/kg) and between the low-level and high-level (> 5 kBq/kg) Ra groups. The available data did not allow us to establish a correlation between external radiation and development of mammary tumors.

Table 44

Average Number of X-ray Examinations Per Dog During Their Lifetimes[a]

Group	Average Number of Exams ± S.D.	"p"[b] Value
All Controls	11.2 ± 7.4	
All Ra dogs	10.5 ± 8.0	
Ra dogs < 5 kBq/kg	7.63 ± 7.4	
Ra dogs > 5 kBq/kg	13.9 ± 7.3	
All Ra vs. All Control		> 0.50
Ra < 5 kBq/kg vs. Control		< 0.05
Ra > 5 kBq/kg vs. Control		> 0.10
Ra dogs, >5 vs. <5 kBq/kg		< 0.001

[a]All examinations are included in the averages (total-body, partial-body, single film, multiple film, etc.), since available records did not always specify the type of x-ray examination performed on a given day. Measurements made on 08 July 1957 indicated that a complete radiographic series produced about 1.81×10^{-4} C/kg (0.7 R) equivalent total body exposure to an adult dog, and similar measurements made on 29 November 1961 after changes had been made in the x-ray equipment and radiographic techniques indicated that the corresponding series delivered about 1.55×10^{-4} C/kg (0.6 R). Records of these modifications, including the exact dates when they were made, were lost during our move to our present facilities (June 1988) following the removal of our dogs from Utah (September 1987) and just prior to the demolition of the buildings that housed our project during the time when the Beagle colony was in operation. Because of the much lower skeletal doses to be expected for Ra dogs at injection levels below about 3 kBq/kg that were introduced into the study after 1963, less complete x-ray examinations were instituted for these 26 animals and for the 31 control dogs entered during the same time period (1964-1967), so that exposure to external radiation continued to constitute only a small fraction of the skeletal dose from radium.
[b]From the Group Comparison ("t") Test.

Although the proportion of mammary tumor occurrence among our Ra-exposed dogs was similar to that of controls (dogs with total tumors were 35/57 = 61% for Ra dogs and 45/63 = 71% for controls, and dogs with malignant tumors were 21/57 = 37% for Ra-exposed dogs and 25/63 = 40% for controls), the age at tumor diagnosis appears to have been decreased significantly among the Ra-exposed dogs. At this time, we can offer no conclusive explanation for the mammary tumor effects that we observed in our dogs. However, at least two possible factors in addition to internal exposure to Ra could have contributed to differences between groups - selective deposition of ^{226}Ra in the mammary glands and differential exposure to X-rays.

3. The Distribution of ^{226}Ra in the Trabecular Skeleton And Cortical Bone of Humans and Beagle Dogs*

W. S. S. Jee, E. Polig**, R. B. Setterberg, and F. Johnson

When using Beagle dogs as an experimental animal for toxicity studies of ^{226}Ra, the physiologic and metabolic differences in the behavior of this radionuclide in dogs and humans has to be considered. The whole-body retention of ^{226}Ra and other alkaline earth elements has been summarized in Publication 20 of the International Commission on Radiological Protection (ICRP 20). The corresponding whole-body retention in the dog has been determined (Lloyd, R. E. *et al. Radiat. Res. 66*: 274, 1976). As Figure 44A shows, the whole-body retention in the two species after a single injection differs widely. At about 3000 days post injection, 0.92% of the injected amount is retained in humans and about 9.3% in dogs. Consequently, for the same specific amount injected (Bq/kg-body weight) and equal time periods, radiation doses to the skeleton of the dog are considerably higher than those to the human skeleton.

Cumulative radiation doses to the skeleton were calculated for humans using the retention equations of ICRP 20 for cortical and cancellous volume labels. The short-term surface labels were disregarded. The contribution from the daughters of ^{226}Ra was considered using the expression of Mays *et al.* (*Health Phys. 29*: 761, 1975) for the fractional retention of ^{222}Rn. The time integrals of the retention functions, as given in ICRP 20, are of little use, because they disregard the contribution from ^{226}Ra-daughters.

As Figure 44B shows, the mean radiation dose to the skeleton during the first 3000 days after a single injection of 37 kBq/kg body weight of ^{226}Ra is about 20 times higher in dogs than in humans. Even if skeletal doses are compared at time periods corresponding to equal fractions of the life expectancy of the species, the radiation doses in the dog may considerably exceed those in humans.

The ICRP 20 model of the alkaline earth metabolism also describes the partitioning of ^{226}Ra between cortical and cancellous bone. The mean concentration in the two skeletal sub-compartments of the human skeleton is plotted in Figure 45A, assuming a single injection of 37 kBq/kg and cortical and cancellous bone masses of 4000 g and 1000 g, respectively. Over the first 3000 days the concentration in cortical bone is lower than in cancellous bone, but with a faster release from the latter. Eventually ICRP 20 predicts that beyond 10^4 days post injection, concentrations in cortical bone exceed those in cancellous bone.

Autoradiographic analysis of the distribution of ^{226}Ra in cancellous and cortical sites of the dog femur shows some similarity to the human findings and is plotted in Figure 45B. The release of ^{226}Ra is slightly faster than in humans, but not fast enough to account for the high turnover rates in the dog metaphysis (123%/y). In addition to information provided in ICRP 20, this might be explained by postulating a local recirculation mechanism of ^{226}Ra in the skeleton which is not systemic.

The hotspots (Polig, E. *et al. Radiat. Prot. Dosim. 3*: 205, 1986) observed in the femur shaft of dogs have a ^{226}Ra concentration about 15 times that of the diffuse label (Fig. 46A). This is about the same ratio as was found in distal femoral metaphysis and epiphysis. The percentage of ^{226}Ra found in hotspots of cortical bone is smaller than in the metaphysis (Fig. 46B), but unlike all trabecular sites, it does not increase with time after injection.

Generally one may conclude that, although the overall level of ^{226}Ra retention in dogs and humans differs widely, the partitioning between cortical and cancellous bone may be quite similar. Also there is not much difference between cortical and trabecular sites within the dog skeleton, in spite of the large differences in bone turnover rates.

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*Radiobiology Division, University of Utah School of Medicine, Salt Lake City, Utah
**Kernforschungszentrum Karlsruhe, Institut für Genetik und Toxikologie von Spaltstoffen, Karlsruhe, Germany

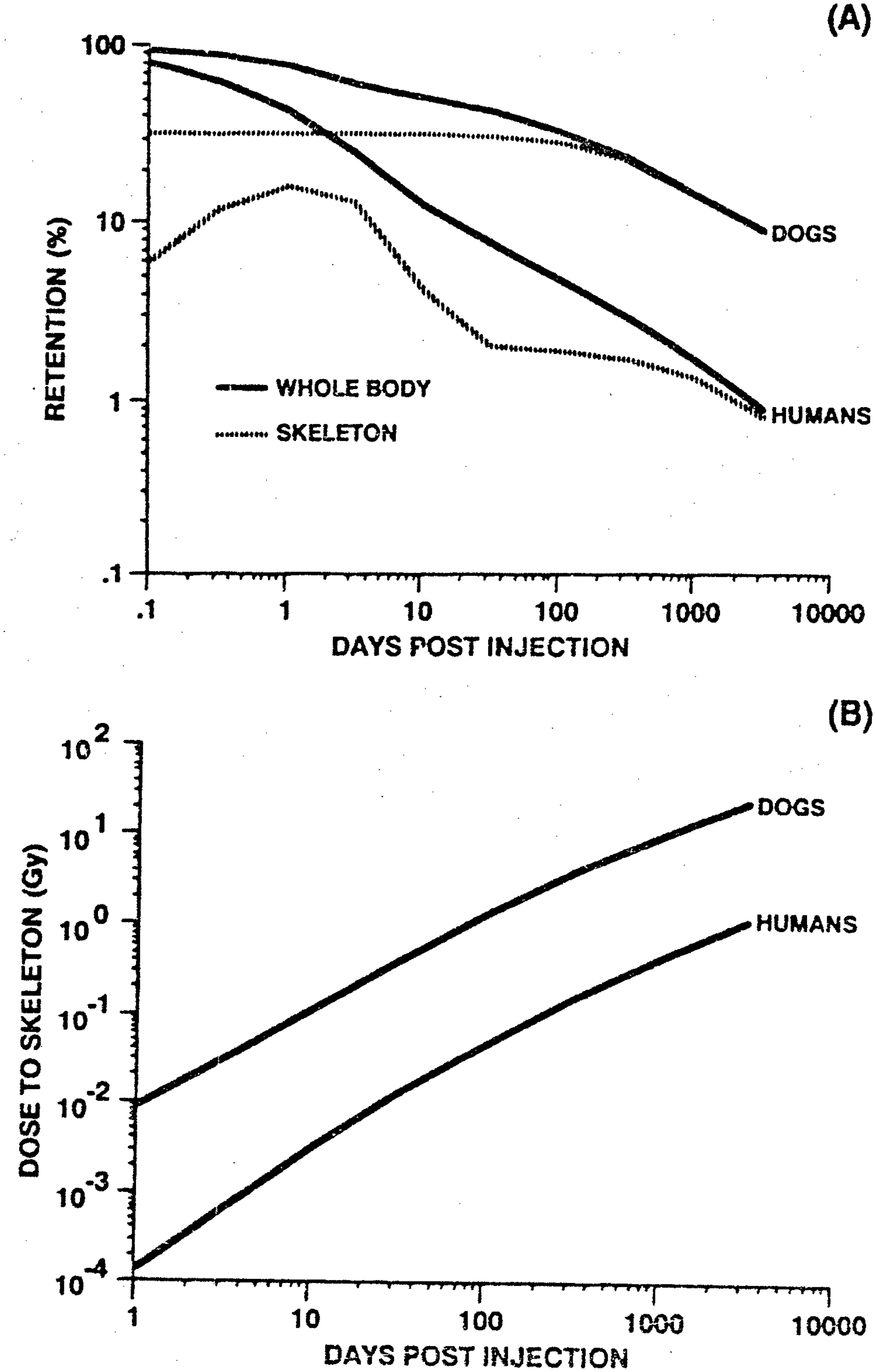

Figure 44. (A) Whole-body retention (solid) and skeletal retention (hatched) of ^{226}Ra in dogs and humans after a single injection. The skeletal retention of humans is without the surface labels. (B) Cumulative radiation dose to the skeleton of dogs and humans after a single injection of 37 kBq/kg body-weight ^{226}Ra.

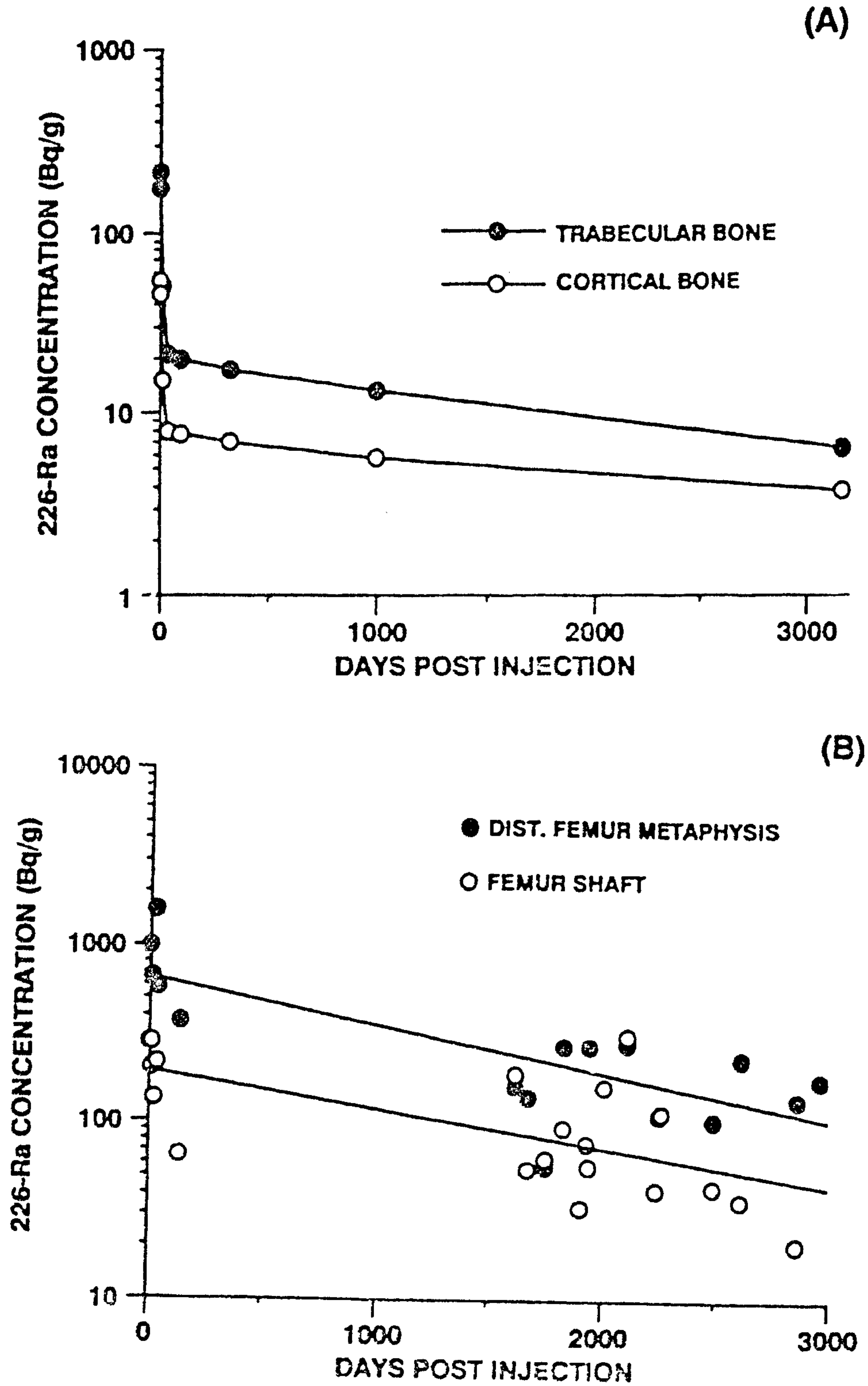

Figure 45. (A) Average concentration of ^{226}Ra in human trabecular and cortical bone after a single injection of 37 kBq/kg body-weight. (B) Average concentration of ^{226}Ra in the femoral metaphysis (trabecular) and the femoral shaft (cortical) of dogs after a single injection of 37 kBq/kg body-weight.

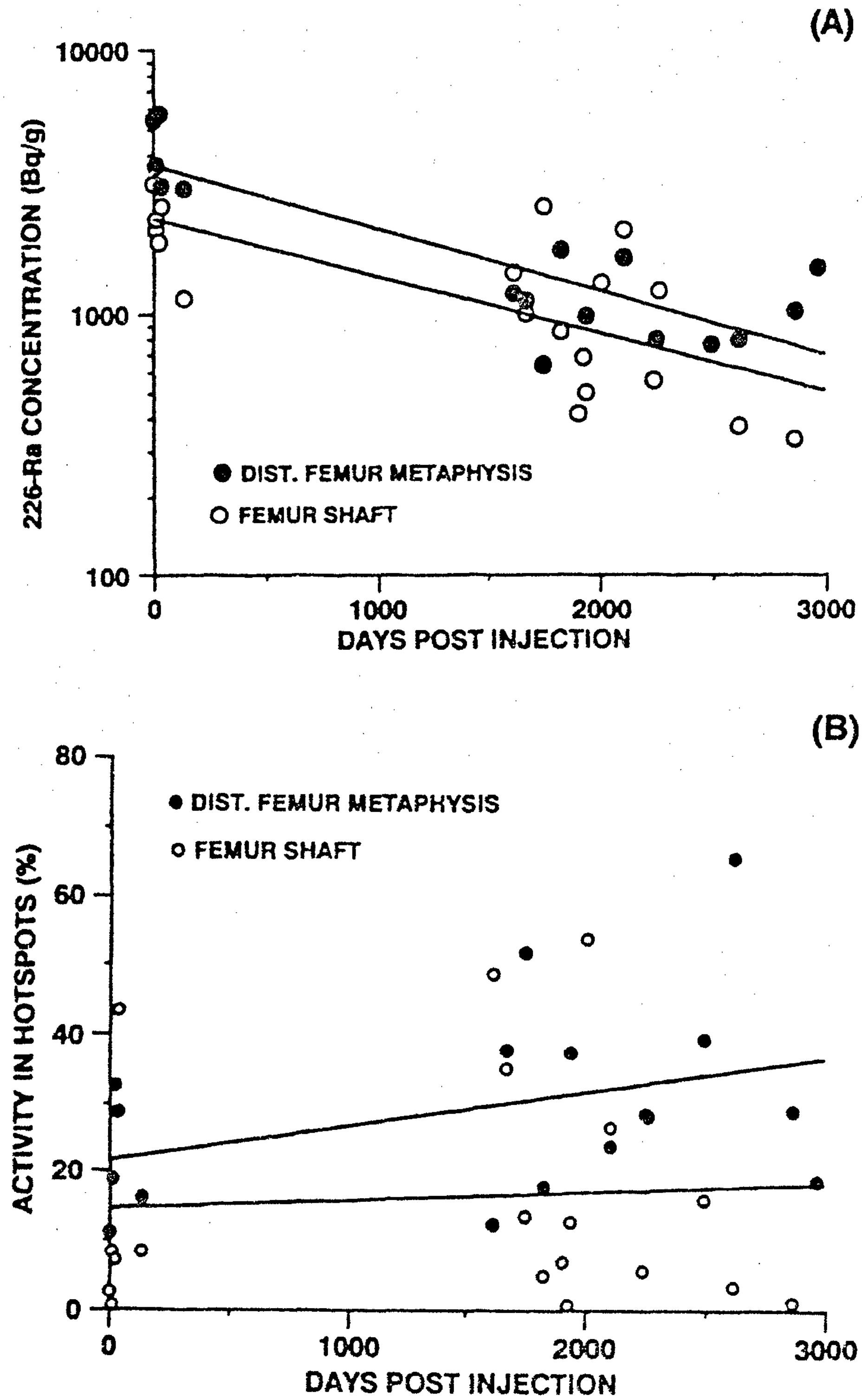

Figure 46. (A) Average concentration of ^{226}Ra in hotspots of the femoral metaphysis (top curve) and shaft (bottom curve) of dogs after a single injection of 37 kBq/kg body-weight. (B) Percentage of ^{226}Ra activity found in hotspots of the femoral metaphysis (top curve) and shaft (bottom curve) of the dog.

4. Hit Factors and Microdosimetric Parameters of the Nuclei of Bone Lining Cells Irradiated By Alpha Emitters*

W. S. S. Jee and E. Polig**

We have shown that the nuclei of osteoblasts, their precursor cells and bone lining cells can be modeled by oblate spheroids (ellipsoids of revolution). The parameters characterizing shape and location, e.g., major and minor axes and distance from surface, have been determined along with their probability densities. In the study described here, the mean values of these parameters are used for the calculation of hit factors, alpha-track segment lengths, energy deposition and radiation dose to cell nuclei of bone-lining cells.

It is primarily the bone lining cell that is subject to irradiation from static volume, surface and "buried" surface deposits of alpha emitters (labels). Osteoblasts and their precursors are present only during cycles of bone formation and are irradiated by dynamically expanding volume labels or shifting surface labels. Therefore, the situation for these types of cells is different and will be treated in a separate investigation.

The hit factor G_H is defined as the factor that relates the local concentration $a_{v,s}$ for either a volume (v) or a surface label (s) of an a-emitting radionuclide to the mean hit rate N of the specified target ($N = G_H a_{v,s}$). G_H and other microdosimetric parameters were determined by means of a Monte Carlo simulation. Figure 47 depicts the irradiation geometry of a spheroidal target characterized by major and minor axes a and b, respectively, whose center is located at a distance c from a cylindrical bone surface. The radius of the bone cylinder is r. In general, a volume label is defined by two concentric cylinders of radius d_1 and d_2 with uniform labeling of the bone between these boundaries.

Equating d_1 and d_2 simulates irradiation from an infinitely thin planar source. Choosing large values of r (>500 μm) simulates the essentially flat surfaces of trabecular bone. Values of 15 μm and 35 μm for r were chosen to represent Haversian canals in cortical bone of Beagle dogs and humans, respectively.

The mean values used for the major and minor axes of the spheroid are 11.1 and 1.6 μm, respectively. The distance c from the surface is 3.1 μm.

Table 47 lists the hit factors, the mean specific energy (dose) in the nucleus per hit and the mean track segment length for both volume and surfaces labels of ^{237}Np, ^{226}Ra (designated at ^{237}Np/^{226}Ra in Table 45), ^{239}Pu and ^{241}Am. These are the a-emitters of major interest with regard to long-term deposition and late toxic effects in the skeleton.

Hit factors for lining cells increase with a-particle energy and decrease with radius r. For the range of a-particle energies most relevant to bone-seeking emitters, hit factors for surface deposits in dog osteons (30 mm dia.) are about 35-40% larger than for trabecular surfaces. For volume deposits, this enhancement due to surface curvature is even more pronounced (40-50%). The effect of surface curvature increases with increasing particle energy because even a curved surface may be considered as essentially flat if the radius of curvature is large compared to the a-particle range.

Surface- and volume-seeking a-emitters can be compared with regard to relative hit frequencies using the specific surface S_v (or surface/volume ratio) and the hit factors listed in Table 45. Ratios of hit frequencies for surface vs. volume sources, assuming an equal amount of radioactivity deposited, are 6 and 19.2 in the trabecular and cortical skeleton of the dog, respectively. The corresponding figures for the human skeleton are 8 and 28.9, respectively. The difference between trabecular and cortical bone comes largely from the different values of S_v in the two types of bone and to a lesser extent from the different irradiation geometries.

*Radiobiology Division, University of Utah School of Medicine, Salt Lake City, Utah
**Kernforschungszentrum Karlsruhe, Institut für Genetik und Toxikologie von Spaltstoffen, Karlsruhe, Germany

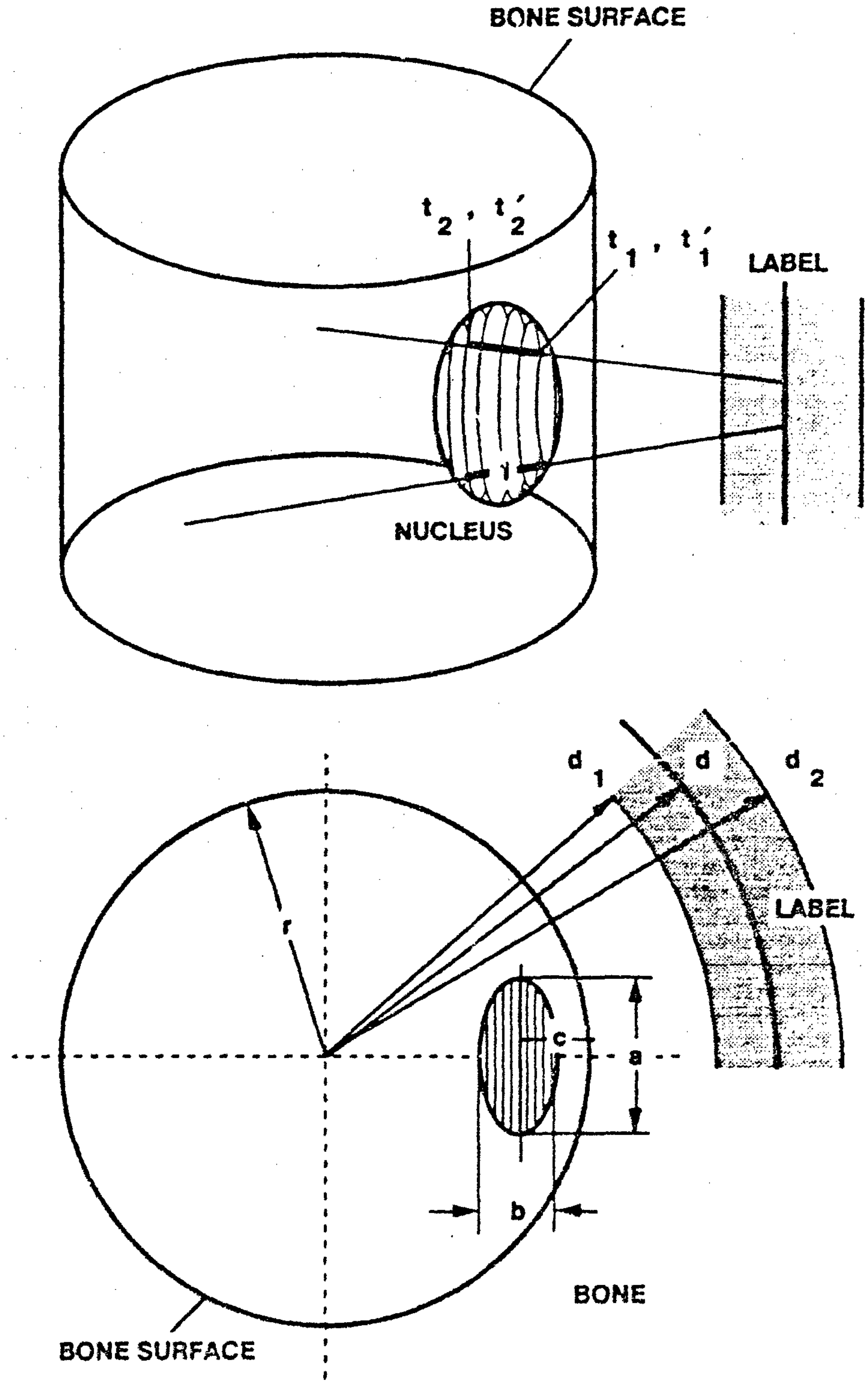

Figure 47. Irradiation of a spheroidal cell nucleus located in a Haversian canal of radius r from an a-emitter. The labeled volume is defined by the radii d_1 and d_2. The particle enters the nucleus at the geometrical distance t_1 and leaves at the distance t_2. t_1' and t_2' are effective distances - larger than the geometrical distances t_1, t_2 (Polig, E. *Phys. Med. Biol. 34*: 353, 1989)

Table 45

Hit Factors, Mean Specific Energies and Track Segment Lengths for Bone Lining Cells from α-Particles of Surface and Volume Sources of $^{237}Np/^{226}Ra$, ^{239}Pu and ^{241}Am

Parameter		$^{237}Np/^{226}Ra$		^{239}Pu		^{241}Am	
		Pl[a]	Cy	Pl	Cy	Pl	Cy
Hit factor (10^{-2} cm^2 Bq^{-1} day^{-1})	SS[b]	4.00	5.38	4.12	5.58	4.13	5.78
(10^{-5} cm^3 Bq^{-1} day^{-1})	VS	3.36	4.67	3.85	5.40	4.26	6.32
Dose/hit (erg/g)	SS	6060	5750	5840	5550	5820	5300
	VS	4480	5170	4420	5000	4280	4930
Track segment length (μm)	SS	2.90	2.71	2.94	2.76	3.08	2.15
	VS	1.81	1.52	1.85	2.04	1.86	2.08

[a]Pl = plane surface, Cy = cylinder 30μm diameter
[b]SS = surface source, VS = volume source

Mean radiation doses (specific energies) for individual particle traversals have been calculated assuming that the energy lost along the track segment intersecting the nucleus is deposited within the volume of the target. This is a stochastic variable, the mean value of which decreases with increasing particle energy due to the decreasing mean linear energy transfer (LET). Within the range of 4-6 MeV for particle energies, the mean dose per hit is 4500-7000 erg/g (0.45 - 0.70 Gy).

Marshall and Groer (Marshall, J. H. and P. G. Groer. In *Energy and Health* [N.E. Breslow and A. S. Whittemore eds.], Proc. SIMS Conference, Alta, Utah, 1978, SIAM, Philadelphia, PA, 1979.) have outlined a model of cell transformation and tumor induction assuming the interaction of two sensitive sites within the nuclear volume. According to this concept, the induction probability is dependent on the mean track segment length and the mean squared track segment length. They also pointed out that differences in dose-effect relationships between surface- and volume-seekers may be attributed to differences of these two parameters for surface and volume sources. Therefore, in this study, the mean track segment length and its variance have been estimated for bone-lining cells. The mean track segment length for a surface label is always larger than for a volume label (Table 45). However, no differences in the dose-effect relationship of volume seekers vs. surface seekers should be expected.

In humans, the ICRP dose equivalent limit of 50 mSv/year for uniform whole-body irradiation corresponds to an endosteal dose rate of 2.28 erg $g^{-1}day^{-1}$. This, in turn, translates into a hit rate of 4.31×10^{-4} day^{-1} or 1.54 hits during the residence time of lining cells at a trabecular turnover rate of 10%/year, or 0.54 hits for 26%/year. Thus, the existing standard for dose limitations implies that a large fraction of nuclei of cells lining bone surfaces is traversed by a-particles.

5. Promotion of Radiation-Induced Liver Neoplasia by Ethanol*

G. N. Taylor, R. D. Lloyd, C. W. Mays**, L. Shabestari***, and S. C. Miller

It is well established that the risk of radiation-induced liver cancer can be increased by various promoting agents that decrease the normally long life span of the hepatocyte, thus promoting the expression of latent radiation injury which is delayed until the occurrence of cell division (Cole, L. J. and P. C. Nowell. *Science 150*: 1782, 1965.) Many agents in our environment tend to accelerate the cell turnover rate in the liver and possibly enhance the expression of latent neoplastic changes (Kraybill, H. F. *International Symposium on Hepatotoxicity* [M. Eliakim *et al.* eds.], Academic Press, New York, p. 122, 1974). In this study, ethanol was selected for evaluation because it has been shown to be a direct hepatotoxin (Rubin, E. and C. S. Leiber. *N. Engl. J. Med. 278*: 869, 1968); to induce hepatic cell regeneration (MacDonald, R. A. *Am. Med. Assoc. Arch. Pathol. 69*: 175, 1960); and because of its wide usage.

All animals used in this experiment were purebred Beagle dogs. The experimental design for the animals receiving ethanol is summarized in Table 1. Baseline data for the natural incidence of liver tumors were derived from life-span observations of 130 nonirradiated, nonethanol-treated dogs. The incidence of radiation-induced liver cancer in nonethanol, americium-treated dogs was determined from 42 other dogs. These latter two groups of dogs have not been tabulated individually, but they were maintained under identical housing and husbandry conditions as those listed in Table 46. Their diet was identical, except that it did not include ethanol, plus they were fed once daily instead of twice daily like the ethanol-treated dogs. All dogs presented in this study were maintained until natural death or until sacrifice became necessary because of terminal disease or humane considerations.

Table 46

Young Adult Dogs in this Study Injected with ^{241}Am Citrate and Given Ethanol (95%) Daily in Their Feed from 35 Days after Injection until Death[a]

Dog	Sex	Age at Inj., Days	Days Inj. to Death	Injected kBq/kg	Weight at Injection, kg	Significant Lesions at Autopsy
T158W0	M	553	5,137	0.0	12.9	Aortic body tumor
T159W0	F	546	3,555	0.0	10.6	Mammary adenocarcinoma
T160W1	F	577	4,408	0.588	11.4	Fibrosarcoma (liver)
T161W1	M	546	1,802	0.588	11.9	Inhalation pneumonia
T162W1	F	546	3,770	0.607	9.64	Cholangiocarcinoma
T163W1	M	544	4,863	0.599	9.32	Epidermoid carcinoma (gum) Cholangiocarcinoma
T164W1.7	M	553	3,366	1.78	11.3	Hepatic cell carcinoma Cholangiocarcinoma
T165W1.7	F	546	1,810	1.81	8.73	Inhalation pneumonia
T166W1.7	M	544	3,452	1.78	9.28	Lymphosarcoma
T167W1.7	F	544	3,340	1.78	9.04	Cholangiocarcinoma

[a]For additional data on the 42 dogs in the nonethanol irradiated groups, see Appendix in *Research in Radiobiology*, Radiobiology Division, University of Utah School of Medicine, Salt Lake City, C00-119-262, pp. A-7 - A-8, 1986.

*Radiobiology Division, University of Utah School of Medicine, Salt Lake City, Utah
**Deceased 3 August 1989 (formerly at the National Cancer Institute, Bethesda, Maryland)
***University of Utah Animal Resources

The ^{241}Am was administered in one intravenous (i.v.) injection at the ages shown in Table 46. The 130 controls were given a single injection of the citrate buffer solution, and the 42 nonethanol, Am-treated dogs were injected with either ~0.58 or ~1.75 kBq ^{241}Am kg^{-1} of body weight at ages comparable to those treated with ethanol. For dose-rate calculations, the blood-filled liver was assumed to comprise 55.4 ± 4 g per kg of body weight (Cuddihy, R. G. *et al. 1971-72 Annual Report*, p. 119; Lloyd *et al. Radiat. Res.* 92: 280, 1982).

Ethanol, in a dosage of 13.5g, was fed twice daily in the standard colony diet. The peak blood ethanol concentrations in animals on this dose ranged from 0.059%-0.093% (w:v), as determined at about 5 yr of age and approximately 3.5 yr following the initiation of the dietary ethanol. Ninety-five percent ethanol was used to avoid benzene residues that are present in 100% ethanol.

Long-term ethanol consumption accelerated the release of Am from the canine liver (Table 47). Accelerated elimination of the radionuclide was first noted at about 1,800 days after injection and became more pronounced with increasing post-treatment times. This represented a net body loss of the Am from the body because the retention equations for non-liver tissue were similar in the ethanol and nonethanol-treated dogs. The reason for the beginning of the increased elimination of ^{241}Am from the livers of ethanol-treated dogs at about 1800 days post-injection was not determined; however, this is approximately the time when the number of radiation-induced hyperplastic nodules begins to increase. These relatively non-radioactive foci, which at the dosage levels considered in this study may ultimately comprise up to 75% of the liver mass, have a complex vascular pattern and probably shunt some of the alcohol-bearing portal blood through the more normal sinusoids of the older non-hyperplastic parenchyma which contains most of the ^{241}Am.

Two long-term, ethanol-treated dogs that did not receive Am were also available for study (Table 46). The principal hepatic lesions in these dogs were: a moderate-to-marked degree of hydropic degeneration of the hepatocytes; a minor and variable degree of fatty degeneration in the hepatocytes but absence of necrosis or increased mitoses; moderate-to-prominent focal hyperplasia and siderosis of the Kupffer cells, which were most extensive in the centrolobular regions; and absence of fibrosis. The liver weights in these two dogs were 511g (12.9 kg body weight at injection) and 348g (10.6 kg body weight at injection), respectively, as compared to 302 ± 71 g for the general control population of the Utah Beagle Colony. Cirrhosis as observed in people (Rubin, E. and C. S. Leiber. *Biochemical and Clinical Aspects of Alcohol Metabolism* [V. M. Sardesai and C. C. Thomas, eds.], C. C. Thomas Press, Springfield, IL, p. 212, 1969) and nonhuman primates (Rubin, E. and C. S. Leiber. *N. Engl. J. Med. 290*: 128, 1974) was not produced.

Extensive focal hyperplasia of the hepatocytes occurred in the dogs receiving the combined ethanol and radiation exposure; however, this was typical of that observed in nonethanol-treated dogs with comparable burdens of Am (Taylor, G. N. *et al.*, *Life-Span Radiation Effects Studies in Animals: What Can They Tell Us?*, Office of Scientific and Technical Information, Springfield, VA, p. 268, 1986) and did not appear to be an ethanol effect. A slight fibrosis was noted in some dogs that received both Am and ethanol.

In the eight Am-treated dogs maintained on the long-term ethanol treatment, five developed one or more primary liver malignancies (Table 46). This incidence translates into a risk coefficient of 5100 liver malignancies (10^4 dog Gy)$^{-1}$ (Table 48) as compared to 2100 liver malignancies (10^4 dog Gy)$^{-1}$ for comparable doses in nonethanol-treated dogs. The calculation of these risk coefficients assumes a linear dose-response relationship. Thus, a 2-3 fold promotion effect, with respect to liver malignancies, was produced by the ethanol treatment. The main uncertainties in this comparison arise principally from the small number of dogs observed - especially in the ethanol-treated groups. Primary liver malignancies did not occur in the two ethanol-treated, nonirradiated, control dogs that received ethanol in their diets for over 14 yr, which is in agreement with the thesis that ethanol is not a major initiating agent of liver tumors (Kissin, B. and M. M. Kaley. *The Biology of Alcoholism* [B. Kissin and H. Begleiter, eds.], Plenum Press, New York, p. 481, 1974). A gender difference in the incidence of radiation-induced liver tumors was not observed.

The tumor-promoting effect of ethanol in the irradiated dogs was observed only in the liver tissue and was probably related to the enhanced turnover rate of hepatocytes (MacDonald, R. A. *et al.*, 1960). An abnormal incidence of cancer in other organs was not associated with the ethanol treatment. This conclusion was based on a comparison of the tumor frequency in the ethanol-treated animals with the incidence in the 130 life-span,

Table 47

Percentage of the Initial Body Burden of Injected ^{241}Am Retained in the Livers of Dogs Given Ethanol (95%) Daily in their Feed as Measured by *In Vivo* Counting, Expressed as Percent of Injected ^{241}Am

Days after Injection	T160 W1	T161 W1	T162 W1	T163 W1	T164 W1.7	T165 W1.7	T166 W1.7	T167 W1.7	Mean	Predicted by the equation[a]
4	51.1	51.9	49.6	48.8	50.7	49.4	53.5	42.7	49.7	49.0
11	47.3	52.4	50.6	44.9	48.1	47.1	48.1	40.0	47.3	48.9
32	52.0	47.9	51.1	47.2	46.5	48.3	47.3	38.5	47.4	48.7
69	49.9	49.7	51.8	48.4	42.9	47.6	49.4	42.1	47.7	48.3
162	49.7	52.9	51.2	41.5	51.8	49.5	49.9	42.9	48.7	47.3
263	47.6	51.7	50.9	36.5	36.5	45.3	52.7	39.9	45.1	46.3
456	49.8	52.6	53.5	45.9					50.4	44.4
462					48.8	49.0	51.5	39.5	47.2	44.4
831					41.8	50.7	43.3	31.4	41.8	41.0
850		51.9	53.0	34.5					46.5	40.8
1,210	38.7	45.6	51.3	24.2	34.8	42.3	39.5	25.6	37.8	37.7
1,802		30.4[b]							30.4	33.2
1,810						19.7[b]			19.7	33.1
2,407					6.6		18.8	3.0	9.5	29.1
2,414	21.6		37.1	10.5					23.1	29.1
3,191	8.7		18.9	6.5	2.7		10.9	2.5	8.4	24.6
3,340								3.8[b]	3.8	23.8
3,452							12.6[b]		12.6	23.3
3,562	7.6		18.0	8.5					11.4	22.7
3,770			13.2[b]						13.2	21.7
4,137	5.5			2.6					4.0	20.1
4,408	8.0[b]								8.0	18.9
4,863				7.7[b]					7.7	17.1

[a]For young adult dogs injected with ^{241}Am but not treated with ethanol, % liver retention = $49.0\ e^{-0.000216t}$, where t = days after injection (Lloyd, R. D. *et al. Radiat. Res. 100*: 564, 1984).
[b]Estimates made from measurement of excised livers.

nonirradiated, control dogs that were reared identically except for the absence of ethanol in their diets. Also, bone cancer was not observed in any ethanol-treated dog, whereas 1.9 tumors were expected. This finding may have been related to the relatively small number of dogs at risk.

Table 48

Calculated Alpha Doses to the Livers of Dogs Injected Intravenously with ^{241}Am

Dog	Days from injection to death	Liver dose 1 yr before death Gy (with alcohol)	Liver dose, Gy at 1 yr before death (no alcohol)	Ratio of calculated liver doses (with/without alcohol)
T160W1	4,408	0.714	1.064	0.67
T161W1	1,802	0.430	0.487	0.88
T162W1	3,770	0.697	0.982	0.71
T163W1	4,863	0.748	1.156	0.65
T164W1.7	3,366	1.947	2.637	0.74
T165W1.7	1,810	1.329	1.507	0.88
T166W1.7	3,452	1.969	2.691	0.73
T167W1.7	3,340	1.940	2.621	0.74

The incidence of liver tumors in dogs with body burdens of Am was increased by a factor of about 2-3 with chronic ethanol ingestion. This was similar to the enhancement effect reported by Cole and Nowell (1965) in mouse studies using neutrons as the initiating agent and carbon tetrachloride as the promoter. Perhaps the maximal ability of the liver to mask potential radiation-induced malignancies is approximately a factor of three. Since it would have been impractical to increase the long-term dose of ethanol used in this experiment to an appreciably higher level, "three" appeared to be near the maximum in this study.

What is the significance of ethanol consumption on the risk coefficients derived from human experience such as the German Thorotrast cases (van Kaick, G. *et al. British Institute of Radiology Report 21* [D. M. Taylor *et al.*, eds.], p. 98, 1989)? For example, in 1970 it was estimated that, in the Federal Republic of Germany, about 5% of the population (15 yr and older) consumed in excess of a daily average of 150 μl of absolute alcohol (DeLing, J. *Brit. J. Addict. 1*: 3, 1975). It is possible that the higher risk observed in the male vs. female German Thorotrast cases might be related to sex differences in ethanol consumption? If ethanol were an enhancing factor in the risk coefficients derived from these cases, the risk coefficients for humans that received Thorotrast would overestimate the risk for individuals without ethanol consumption.

Paradoxically, ethanol tended to shorten the Am retention time, thus reducing the radiation dose, while simultaneously promoting the development of radiation-induced tumors. However, the net result of these opposing factors was still a significant increase in the risk of liver malignancies, even though the enhanced Am excretion from the liver probably provided some protective effect. Obviously, the dominance of the tumor-promoting effect of ethanol plus other undesirable factors would preclude any therapeutic consideration of its use as a means of reducing a radionuclide burden in the liver.

In this study, involving a relatively small number of dogs, chronic ingestion of ethanol exerted an appreciable promoting effect on radiation-induced malignancies in the liver. Restriction of dietary ethanol should possibly be considered as part of the treatment regimen in human cases involving liver irradiation.

III. ARGONNE NATIONAL LABORATORY LIFE-SPAN STUDIES IN DOGS

A. SPECIFIC PROJECT OBJECTIVES

Studies have been in progress at the Argonne National Laboratory for many years to study the long-term biological effects of protracted ^{60}Co irradiation in laboratory dogs. Because the dog has a much longer life-span than rodents, results from the dog are providing a bridge for extrapolating results between rodent data and what would be projected for people irradiated under similar conditions. The previously stated objectives of these studies were to (1) determine the relative influence of daily exposure rate and total accumulated dose, (2) provide data for estimates of radiation-specific excess mortality rates in the dog to enable interspecies comparisons with existing rodent data, and (3) study the radiation damage related to life shortening and death, particularly leukemia and other pathology of the blood-forming system. The radiation-exposed dogs in these studies received protracted whole-body ^{60}Co irradiation for 22 hours/day, 7 days/week, at various dose rates down to those allowing a nearly normal life-span. Other dogs that were housed under the same conditions but were not exposed to the ^{60}Co radiation served as controls.

The basic studies initiated at the Argonne National Laboratory to study the effects of protracted whole-body irradiation of dogs have been primarily of two types: life-span and terminated. In the life-span studies, Beagle dogs were entered on study as young adults and irradiated chronically 22 hours per day, 7 days per week, at different dose rates (0.3, 0.75, or 1.9 cGy per day) over their remaining life span. In the terminated-type of study, dogs were chronically exposed under a similar regimen at dose rates of 3.8, 7.5, 12.8, or 26.3 cGy per day until predetermined total doses of 450, 1050, 1500, or 3000 cGy were accumulated. The irradiation of these dogs has been completed or stopped, and most of the dogs are now dead.

B. CURRENT STATUS OF DOGS

The study population alive in January 1991 was comprised of colony controls, study dogs who were being exposed at the 0.3 cGy per day level and the associated controls. In addition, other dogs were on long-term study of the hematopoietic effects of different regimens of protracted irradiation from an external ^{60}Co source. At that time, a decision was made to discontinue the chronic irradiation of the remaining dogs on study and to transfer all remaining dogs to ITRI for care, clinical observations, and pathological evaluations at death or euthanasia. A total of 73 dogs were transferred to the ITRI colony on January 23, 1991 and are receiving appropriate life-span followup observations (Table 49).

From January, 1991, to September 30, 1991, 16 dogs died or were euthanized in the study, *Protracted Whole-Body ^{60}Co Irradiation*. Seven of the 16 dogs died with neoplastic disease, a prevalence similar to that of control dogs in the ITRI colony. No clear pattern of site or tumor type emerges from these data. Two dogs died in the *Colony Control* group. One of these dogs died with neoplastic disease. None of the dogs in the other studies died. All of the surviving dogs continue to be followed medically, and gross and histopathology information will be obtained at death.

Table 49

Status of Dogs Transferred from Argonne National Laboratory to ITRI on January 23, 1991

Study Name	Tattoo	Sex	Birth Date	Death Date	Death Age	Gross Findings
Protracted Whole-Body ^{60}Co Irradiation 0.3 Cgy/day	3020	F	75046	91075	5873	Acute Hepatitis, Nodular Hyperplasia-Liver
	3234	F	76105	91094	5468	Glomerulonephritis, Severe Chronic
	3244	F	76114	91059	5424	Mammary Carcinoma with Metastasis
	3247	M	76114	91104	5469	Congestive Heart Failure, Secondary to Myocardial Degeneration
	3262	M	76119			
	3287	M	76132	91245	5592	Kidney Carcinoma, Metastasis to Adrenal, Thyroid, L. Node
	3300	M	76173			
	3309	M	76174			
	3363	M	76292			
	3364	M	76292			
	3368	F	76293			
	3374	M	76293			
	3377	M	76302	91077	5254	Lung Necrosis, Seizures
	3378	F	76302			
	3385	M	76302			
	3410	M	76306	92003	5541	Thyroid Carcinoma, with Metastasis
	3418	M	76308			
	3432	F	76325	91225	5379	Disc Degeneration, Pyelonephritis, Liver Degeneration
	3433	F	76325			
	3447	F	76331	91192	5340	Diverse Clinical and Gross Findings, No PCOD Yet
	3456	M	76334	92104	5614	Hydrocephalus, Pheochromocytoma
	3543	M	77164			
	3544	M	77164			
	3549	M	77172	91157	5098	Right Heart Failure, Liver Chronic Passive Congestion, Seizures
	3552	F	77180	92169	5467	Lung - Adenocarcinoma

Table 49

Status of Dogs Transferred from Argonne National Laboratory to ITRI on January 23, 1991

Study Name	Tattoo	Sex	Birth Date	Death Date	Death Age	Gross Findings
Protracted Whole-Body ^{60}Co Irradiation 0.3 Cgy/day (Cont.)	3555	F	77180			
	3571	F	77195			
	3572	F	77195	91073	4991	Mammary Neoplasia with Metastasis
	3575	F	77195	91204	5122	Myocardial Infarction
	3576	M	77195	91135	5053	Chronic Pyelonephritis
	3590	F	77238			
	3602	F	77270	91207	5050	Adrenal Cortical Carcinoma
Hematologic Changes in Radiation Induced Leukemia	4171	F	84220			
	4173	M	84220			
	4178	M	84223			
	4230	M	86034			
	4231	M	86034			
	4236	M	86081			
	4238	M	86081			
	4319	F	86305			
	4446	M	88044			
	4449	M	88045			
	4512	M	89137			
	4518	M	89138			
	4524	M	89144			
	4525	M	89144			
	4532	M	89148			
	4535	M	89148			
	4541	M	89148			
	4549	M	89187			
	9001	F	81008			
Fractionated Weekly Doses from ^{60}Co External Irradiation	4358	M	87129			
	4405	M	87207			
	4427	M	87343			

Table 49

Status of Dogs Transferred from Argonne National Laboratory to ITRI on January 23, 1991

Study Name	Tattoo	Sex	Birth Date	Death Date	Death Age	Gross Findings
Continuous Irradiation *In Utero*	3055	F	75118			
	4147	F	83308			
	4148	F	83308			
	4150	F	83308			
Cadonium Metabolism in Dogs	3917	F	81112			
	9009	F	83185			
Colony Controls	3542	M	77164			
	3591	M	77238			
	3618	M	77341	91214	4986	Ruptured Disk, Cord Compression
	3695	F	78171	91144	4721	Ovary-Tumor, Liver-Fibrosarcoma
	3752	M	78179			
	3784	M	79127			
	3835	M	79267			
	3909	M	81111			
	3936	M	81175			
	3991	M	82005			
	4161	F	84003			

IV. PUBLICATIONS FROM THE LIFE-SPAN STUDIES IN DOGS AT THE ITRI

A. OPEN-LITERATURE PUBLICATIONS FROM INCEPTION OF THE ITRI STUDIES THROUGH FY-1990 (Total of 309)

Full references to these publications are given in : *Annual Report on Long-Term Dose-Response Studies of Inhaled or Injected Radionuclides; 1988-1989*, pp. 129-150, Report LMF-128 (1990) and *1989-1990*, pp. 157-159, Report LMF-130 (1991).

B. OPEN-LITERATURE PUBLICATIONS OF THE ITRI STUDIES DURING FY-1991 (Total of 33)

Benjamin, S. A., K. J. Nikula, B. A. Powers and F. F. Hahn: Radiation and Heat. In *A Handbook of Toxicologic Pathology*, (W. M. Haschek-Hock and C. G. Rousseaux, eds.), Academic Press, 1991.

Bice, D. E., D. N. Weissman and B. A. Muggenburg: Long-Term Maintenance of Localized Antibody Responses in the Lung. *Immunology* (in press).

Boecker, B. B., B. A. Muggenburg, F. F. Hahn, K. J. Nikula and W. C. Griffith: Life-Span Health Effects of Relatively Soluble Forms of Internally Deposited Beta-Emitting Radionuclides. To be published in *Proceedings of the International Radiation Protection Association 8th Congress*, to be held in Montreal Quebec, Canada, May 1992 (in press).

Boecker, B. B., R. M. Hall, Jr. , K. G. W. Iun, J. N. P. Lawrence and P. L. Ziemer: Current Status of Bioassay Procedures to Detect and Quantify Previous Exposures to Radioactive Materials. *Health Phys. 60(1)*: 45-100, 1991.

Brooks, A. L., R. A. Guilmette, F. F. Hahn, P. J. Haley, B. A. Muggenburg, J. A. Mewhinney and R. O. McClellan: Distribution and Biological Effects of Inhaled $^{239}Pu(NO_3)_4$ in the Cynomolgus Monkey. *Rad. Research* (submitted).

Chang, I. Y., W. C. Griffith, L. J. Shyr, H. C. Yeh, R. G. Cuddihy and F. A. Seiler: Software for the Draft NCRP Respiratory Tract Dosimetry Model. *Radiat. Prot. Dosim.* (in press).

Davila, D. R., R. A. Guilmette, D. E. Bice, B. A. Muggenburg, D. S. Swafford and P. J. Haley: Long-Term Consequences of $^{239}PuO_2$ Exposure in Dogs: Persistent T Lymphocyte Dysfunction. *Int. J. Radiat. Biol.* (in press).

Diel, J. H., R. A. Guilmette, B. A. Muggenburg, F. F. Hahn and I.-Y. Chang: Influence of Dose Rate on Survival Time for $^{239}PuO_2$ Induced Radiation Pneumonitis or Pulmonary Fibrosis in Beagles. *Radiat. Res.* (in press).

Gillett, N. A., R. R. Pool, G. N. Taylor, B. A. Muggenburg and B. B. Boecker: Strontium-90 Induced Bone Tumors in Beagle Dogs: Effects of Route of Exposure and Dose Rate. *Int. J. Radiat. Biol.* (submitted).

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Gillett, N. A., B. L. Stegelmeier, G. Kelly, P. J. Haley and F. F. Hahn: Expression of Epidermal Growth Factor Receptor in Plutonium-239 Induced Lung Neoplasms in Dogs. *Vet. Pathol.* (in press).

Gillett, N. A., B. L. Stegelmeier, I.-Y. Chang and G. Kelly: Expression of Transforming Growth Factor Alpha in Plutonium-239 Induced Lung Neoplasms in Dogs: Investigations of Autocrine Mechanisms of Growth. *Radiat. Res. 126*: 289-295, 1991.

Griffith, W. C., B. B. Boecker, N. A. Gillett, R. A. Guilmette, F. F. Hahn and B. A. Muggenburg: Comparison of Risk Factors for Bone Cancer Induced by Inhaled $^{90}SrCl$ and $^{238}PuO_2$. *Proceedings of the EULEP/DOE Joint Bone Radiobiology Workshop*, VCD-472-136, pp. 13-16, NTIS, Springfield, VA, 1991.

Griffith, W. C., B. B. Boecker, F. F. Hahn, B. A. Muggenburg and M. B. Snipes: The Effect of Dose Protraction on the Incidence of Lung Carcinomas in Beagle Dogs with Internally Deposited B-Emitting Radionuclides. To be published in *Proceedings of the International Radiation Protection Association 8th Congress*, to be held in Montreal, Quebec, Canada, May 1992 (in press).

Griffith, W. C. and R. A. Guilmette: Multiparameter Analysis of Fallout Plutonium Burdens in Human Liver. *Radiat. Prot. Dosim.* (in press).

Guilmette, R. A. and A. F. Eidson: Using Animal Dosimetry Models to Interpret Human Bioassay Data for Actinide Exposures. *Int. J. Radioanalytical Nucl. Chem.* (in press).

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C. DOCUMENT REPORTS RESULTING FROM THE ITRI STUDIES

Report No.	Date	Title
LF-28	Sep 1965	Selective Summary of Studies on the Fission Product Inhalation Program from July 1964 through June 1965
LF-33	Nov 1966	Selective Summary of Studies on the Fission Product Inhalation Program from July 1965 through June 1966
LF-38	Nov 1967	Fission Product Inhalation Program Annual Report, 1966-1967
LF-39	Nov 1968	Fission Product Inhalation Program Annual Report, 1967-1968
LF-41	Nov 1969	Fission Product Inhalation Program Annual Report, 1968-1969
LF-43	Nov 1970	Fission Product Inhalation Program Annual Report, 1969-1970
LF-44	Nov 1971	Fission Product Inhalation Program Annual Report, 1970-1971
LF-45	Nov 1972	Fission Product Inhalation Program Annual Report, 1971-1972
LF-46	Dec 1973	Inhalation Toxicology Research Institute Annual Report, 1972-1973
LF-49	Dec 1974	Inhalation Toxicology Research Institute Annual Report, 1973-1974
LF-52	Dec 1975	Inhalation Toxicology Research Institute Annual Report, 1974-1975
LF-56	Dec 1976	Inhalation Toxicology Research Institute Annual Report, 1975-1976
LF-58	Dec 1977	Inhalation Toxicology Research Institute Annual Report, 1976-1977
LF-60	Dec 1978	Inhalation Toxicology Research Institute Annual Report, 1977-1978
LF-69	Dec 1979	Inhalation Toxicology Research Institute Annual Report, 1978-1979
LMF-84	Dec 1980	Inhalation Toxicology Research Institute Annual Report, 1979-1980
LMF-91	Dec 1981	Inhalation Toxicology Research Institute Annual Report, 1980-1981
LMF-102	Dec 1982	Inhalation Toxicology Research Institute Annual Report, 1981-1982

Report No.	Date	Title
LMF-107	Dec 1983	Inhalation Toxicology Research Institute Annual Report, 1982-1983
LMF-113	Dec 1984	Inhalation Toxicology Research Institute Annual Report, 1983-1984
LMF-114	Dec 1985	Inhalation Toxicology Research Institute Annual Report, 1984-1985
LMF-115	Dec 1986	Inhalation Toxicology Research Institute Annual Report, 1985-1986
LMF-120	Dec 1987	Inhalation Toxicology Research Institute Annual Report, 1986 1987
LMF-121	Dec 1988	Inhalation Toxicology Research Institute Annual Report, 1987-1988
LMF-128	Aug 1990	Annual Report on Long-Term Dose-Response Studies of Inhaled or Injected Radionuclides, 1988-1989
LMF-130	Mar 1991	Annual Report on Long-Term Dose-Response Studies of Inhaled or Injected Radionuclides, 1989-1990
LMF-135	Mar 1992	Annual Report on Long-Term Dose-Response Studies of Inhaled or Injected Radionuclides, 1990-1991 (this report)

V. PUBLICATIONS FROM LIFE-SPAN STUDIES IN DOGS AT THE UNIVERSITY OF UTAH

A. OPEN-LITERATURE PUBLICATIONS FROM INCEPTION OF THE UTAH STUDIES THROUGH FY-1990 (Total of 373)

Full references to these publications are given in: *Annual Report on Long-Term Dose-Response Studies of Inhaled or Injected Radionuclides; 1988-1989*, pp. 151-176, Report LMF-128 (1990) and *189-1990*, pp. 163-164, report LMF-130 (1991).

B. OPEN-LITERATURE PUBLICATIONS OF THE UTAH STUDIES DURING FY-1991 (Total of 22)

Bruenger, F. W., G. Kuswik-Rabiega and S. C. Miller: Decorporation of Aged Actinide Deposits by Oral Administration of Lipophilic Polyaminocarboxylic Acids. *J. Medicinal Chemistry* (in press).

Bruenger, F. W., R. D. Lloyd and S. C. Miller: The Influence of Age at Time of Exposure to ^{226}Ra or ^{239}Pu on Distribution, Retention, Postinjection Survival and Tumor Induction in Beagle Dogs. *Radiat. Res. 125*:248-256, 1991.

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C. DOCUMENT REPORTS RESULTING FROM THE UTAH STUDIES

Report No.	Date	Title
TID-7639	Jun 1954	Consultants Meeting
AECU-3418	Mar 1955	Annual Report
AECU-3109	Sep 1955	Semi-Annual Report
TID-16458	Mar 1956	Annual Report
TID-16459	Sep 1956	Semi-Annual Report
AECU-3522	Mar 1957	Annual Report
AECU-3583	Sep 1957	Semi-Annual Report
COO-215	Mar 1958	Annual Report
COO-216	Mar 1958	Escape of Radon and Thoron
COO-217	Sep 1958	Semi-Annual Report
AECU-4112	Feb 1959	Radioactive Fallout
COO-218	Mar 1959	Annual Report
COO-219	Sep 1959	Semi-Annual Report
COO-220	Mar 1960	Research in Radiobiology
COO-221	Aug 1960	Interim Report of ^{90}Sr
COO-222	Sep 1960	Research in Radiobiology
COO-223	Mar 1961	Research in Radiobiology
COO-224	Sep 1961	Research in Radiobiology
COO-225	Mar 1962	Research in Radiobiology
COO-226	Sep 1962	Research in Radiobiology
COO-227	Mar 1963	Research in Radiobiology
COO-228	Sep 1963	Research in Radiobiology
COO-119-229	Mar 1964	Research in Radiobiology
COO-119-230	Jul 1964	(Superseded by COO-119-245)
COO-119-231	Sep 1964	Research in Radiobiology
COO-119-232	Mar 1965	Research in Radiobiology
COO-119-233	Sep 1965	Research in Radiobiology
COO-119-234	Mar 1966	Research in Radiobiology
COO-119-235	Sep 1966	Research in Radiobiology
COO-119-236	Mar 1967	Research in Radiobiology
COO-119-237	Mar 1968	Research in Radiobiology
COO-119-238	Aug 1968	Rb in RBC, Plasma, and Urine

Report No.	Date	Title
COO-119-239	Dec 1968	Cs, Rb, and K Metabolism
COO-119-240	Mar 1969	Research in Radiobiology
COO-119-241	Mar 1970	Retention and Dosimetry
COO-119-242	Jan 1971	Research in Radiobiology
COO-119-243	Jan 1971	Osteosarcoma Growth Dynamics
COO-119-244	Mar 1971	Research in Radiobiology
COO-119-245	May 1971	(Superseded by COO-119-255)
COO-119-246	Mar 1972	Research in Radiobiology
COO-119-247	Oct 1972	Rb and Cs Metabolism
COO-119-248	Mar 1973	Research in Radiobiology
COO-119-249	Mar 1975	Research in Radiobiology
COO-119-250	Mar 1975	Research in Radiobiology
COO-119-251	Mar 1976	Research in Radiobiology
COO-119-252	Mar 1977	Research in Radiobiology
COO-119-253	Mar 1978	Research in Radiobiology
COO-119-254	Mar 1979	Research in Radiobiology
COO-119-255	Jan 1980	Radiobiology Safety Manual
COO-119-256	Mar 1980	Research in Radiobiology
COO-119-257	Mar 1982	Research in Radiobiology
COO-119-258	Mar 1983	Research in Radiobiology
COO-119-259	Dec 1984	Research in Radiobiology
COO-119-261	Dec 1985	Research in Radiobiology
COO-119-262	Dec 1986	Research in Radiobiology
COO-119-263	Dec 1987	Research in Radiobiology
COO-119-264	Dec 1988	Research in Radiobiology
LMF-121	Dec 1988	ITRI Annual Report
LMF-128	Aug 1990	Annual Report on Long-Term Dose-Response Studies of Inhaled or Injected Radionuclides, 1988-1989
LMF-130	Mar 1991	Annual Report on Long-Term Dose-Response Studies of Inhaled or Injected Radionuclides, 1989-1990
LMF-135	Mar 1991	Annual Report on Long-Term Dose-Response Studies of Inhaled or Injected Radionuclides, 1990-1991 (this report)

APPENDIX A: STATUS OF LONGEVITY AND SACRIFICE STUDIES IN BEAGLE DOGS AT ITRI (9/30/91)

Data in this appendix are preliminary estimates through September 30, 1991, of (a) total body or organ contents and (b) the resultant radiation dose received by individual dogs that have been assigned to longevity or sacrifice studies. These estimates are provided as an information source for scientists in this laboratory and others who desire to follow the progress of these studies. It must be emphasized that these data are preliminary and based on results that may be inaccurate or incomplete at the time these tables were prepared. Although the data represent the best information currently available, it must be noted that, with time, certain values and diagnoses will be modified and updated as new and better information becomes available. This information has not, as yet, received the overall vigorous review and analysis by the respective investigators that is required before these data can be used in subsequent analyses. Readers are cautioned against using these data for independent dose-response modeling or other analytical efforts by other scientists until the principal ITRI investigators have had the opportunity to perform the necessary basic data reviews and analyses and publish reports on these studies.

An expedited effort is underway to complete these reviews and publications. When the reviews have been completed and the basic results published in the peer-reviewed literature, the investigators will be very interested in exploring collaborative efforts of mutual interest with other investigators to maximize the ways in which these valuable data are ultimately used.

RADIOACTIVITY CONTENT

Initial body burden (IBB) is defined as the best current estimate of the total radionuclide content within the body immediately after an inhalation exposure or intravenous injection.

Long-term retained burden (LTRB) is defined as the best current estimate of the amount of radionuclide remaining in the body after early clearance of the nasopharyngeal and tracheobronchial regions via the gastrointestinal tract. The term is used in these tables to describe the type of body burden resulting from inhalation of a radionuclide in a relatively soluble form. It is related to the amount of radionuclide deposited in the entire respiratory tract, and not just to the fraction deposited in the pulmonary region.

Initial lung burden (ILB) is defined as the long-term retained burden associated with the inhalation of relatively insoluble particles. In this case, essentially all of the body burden remaining after early clearance of the nasopharyngeal and tracheobronchial regions is in the pulmonary region.

CLINICOPATHOLOGICAL FEATURES

Comments are tabulated for the current interpretation of the most prominent clinicopathological features associated with the death of animals. It should be recognized that many animals have multiple tumors or other lesions, not all of which can be listed in a summary table. Diagnoses are discussed in greater detail in the text of this and preceding reports, and in open literature publications.

RADIATION DOSE CALCULATIONS

The methods used in establishing the radiation dose parameters presented have been described in the text of the report or referenced to previous reports. A key consideration in these calculations is tissue weight, because absorbed dose is inversely proportional to tissue weight. Tissue weights used for the calculated dose values reported in Appendix A have changed over the years; it is important that the reader be aware of these changes and the rationale behind them.

Lung weights used in the earliest reported dose calculations (1966-67 Annual Report, LF-38, pp. 19-64 and 1967-68 Annual Report, LF-39, pp. 14-75) were based on a (lung weight)/(body weight) radio of 0.0075 determined from tissue weights from exsanguinated dogs. This ratio was changed to 0.014 in the 1968-69 Annual Report (LF-41, pp. 27-28), based on calculations of the estimated weight of lung with its normal complement of blood in the living dog. Subsequent experimental evidence reported in the 1971-72 Annual Report, (LF-45,

pp. 119-128) indicated that this value was too high. Based on these results, our best estimate of the (lung weight (with blood))/(body weight) ratio is 0.011. This value has been used for all dose calculations for dog lungs in all annual report appendices, beginning with those in 1972-73 Annual Report, LF-46.

Liver weights used in early reports were calculated using a (liver weight)/(body weight) ratio of 0.027, which was based on tissue weights from exsanguinated dogs. The ratio was used for dose calculations in all reports through the 1971-72 Annual Report, LF-45. Based on experimental data presented on LF-45, the best estimate for the (liver weight (with blood))/(body weight) ratio is 0.050. This value has been used for all dose calculations for dog liver beginning with the 1972-73 Annual Report, LF-46.

Skeleton weights have always been calculated on the basis of a (skeleton weight)/(body weight) ratio of 0.10.

Tracheobronchial lymph node weights are based on a (tracheobronchial lymph node weight)/(body weight) ratio of 0.00005.

APPENDIX B: STATUS OF LONGEVITY AND SACRIFICE STUDIES IN BEAGLE DOGS FROM THE UNIVERSITY OF UTAH (9/30/91)

STATUS TABLES

A.1 $^{90}SrCl_2$, Longevity Study

DOG IDENTIFICATION TATTOO	AN-EXPT	SEX	INHALATION EXP. DATE	AGE DAYS	WT KG	I.B.B. RANK	MBQ/KG	MBQ	L.T.R.B. RANK	UCI/KG	MBQ/KG	BETA RADIATION DOSE TO SKE — DOSE RATE (GY/DAY) INITIAL	730 DAYS	POTENT.AT 5000 DAYS	AT DEATH	73 DAY
157E	01-416	F	67115	431	9.7	01	10.	100.	01	120.	4.4	.55	.21	.070	.21	180.
16[illegible]A	02-419	M	67124	387	9.0	09	7.8	70.	02	120.	4.4	.54		.013	.24	
158E	02-416	F	67115	429	10.2	06	8.9	89.	03	120.	4.4	.54	.16	.053	.15	140.
195C	03-456	F	67275	397	9.3	03	10.	93.	04	110.	4.1	.48			.30	
195B	02-456	M	67275	397	10.1	04	9.6	96.	05	100.	3.7	.48			.34	
162F	01-419	F	67124	436	11.2	02	10.	110.	06	100.	3.7	.47	.21	.037	.20	180.
158B	03-416	M	67115	429	9.3	05	8.9	81.	07	100.	3.7	.47			.36	
159B	02-417	F	67117	430	9.8	08	8.1	78.	08	98.	3.6	.45			.29	
160B	02-418	M	67122	435	9.5	07	8.5	81.	09	97.	3.6	.44	.18	.062	.17	150.
23C	01-261	M	65229	408	9.1	11	5.9	56.	10	83.	3.1	.37	.15	.057	.14	130.
159A	01-417	M	67117	430	11.3	10	6.7	74.	11	74.	2.7	.34			.25	
160C	03-417	F	67117	430	10.4	12	5.9	59.	12	69.	2.6	.31	.075	.032	.068	70.
23B	02-256	M	65208	387	8.0	17	4.1	33.	13	59.	2.2	.27	.081	.023	.059	76.
26F	03-263	F	65231	384	7.8	15	4.4	34.	14	52.	1.9	.24	.090	.037	.064	89.
13A	02-228	M	65123	381	8.3	19	3.7	30.	15	51.	1.9	.23	.066	.019	.054	64.
12F	01-228	F	65123	401	8.1	18	4.1	34.	16	50.	1.9	.26	.086	.045	.080	79.
162A	01-418	M	67122	434	11.9	13	4.8	56.	17	50.	1.9	.23	.095	.023	.060	88.
22E	02-257	F	65209	396	6.7	21	3.4	23.	18	44.	1.6	.20	.047	.015	.024	47.
26A	01-262	M	65230	383	7.8	14	4.4	35.	19	41.	1.5	.19	.064	.024	.053	64.
19B	01-252	M	65201	404	6.4	23	3.1	20.	20	40.	1.5	.18	.038	.013	.021	39.
22F	01-256	F	65208	395	8.8	16	4.4	37.	21	34.	1.3	.16	.062	.026	.051	59.
19C	02-252	F	65201	404	7.8	22	3.2	25.	22	28.	1.0	.13	.033	.014	.019	33.
22A	02-253	M	65202	389	10.5	20	3.6	37.	23	28.	1.0	.12	.061	.015	.035	61.
19D	01-253	F	65202	405	8.7	24	2.6	23.	24	27.	1.0	.12	.034	.013	.021	35.
40E	03-283	F	65301	383	6.3	28	1.0	6.3	25	9.6	0.36	.044	.015	.0061	.0068	15.
28C	02-271	M	65256	406	7.6	26	1.1	8.5	26	9.3	0.34	.043	.014	.0056	.0084	15.
39C	02-283	F	65301	385	8.7	29	1.0	8.5	27	9.1	0.34	.042	.042	.0035	.0035	11.
38E	01-283	F	65301	391	6.5	27	1.1	7.0	28	8.9	0.33	.040	.0081	.0025	.0025	8.
30C	02-272	M	65257	395	8.5	32	0.70	5.9	29	8.3	0.31	.037	.011	.0033	.0040	12.
30B	01-272	M	65257	395	8.2	35	0.63	5.2	30	7.9	0.29	.036	.0090	.0030	.0032	9.
42D	01-284	F	65302	377	7.8	30	0.93	7.0	31	7.7	0.28	.036	.011	.0030	.0030	11.
28B	01-271	M	65256	406	7.2	25	1.2	8.5	32	7.1	0.26	.032	.010	.0030	.0050	11.
22D	01-257	M	65209	396	9.1	36	0.59	5.2	33	6.8	0.25	.031	.0088	.0031	.0031	9.
30D	03-272	M	65257	395	8.9	31	0.85	7.4	34	6.6	0.24	.030	.0091	.0028	.0039	9.
42E	02-284	F	65302	377	8.7	33	0.70	6.3	35	6.1	0.23	.028	.0083	.0028	.0033	8.
42F	03-284	F	65302	377	7.3	34	0.63	4.8	36	5.7	0.21	.026	.0059	.0019	.0020	6.
26B	01-266	M	65238	391	9.0	37	0.24	2.2	37	3.2	0.12	.015	.0041	.00077	.00090	4.
35E	02-277	F	65271	380	7.5	38	0.20	1.5	38	2.3	0.085	.010	.0033	.0016	.0017	3.
30G	01-277	F	65271	409	7.0	39	0.17	1.2	39	2.2	0.081	.010	.0037	.0012	.0013	3.
27D	02-267	F	65239	390	10.6	41	0.15	1.6	40	2.2	0.081	.0098	.0019	.00035	.00039	1.
27A	03-266	M	65238	389	9.1	43	0.15	1.3	41	1.9	0.070	.0087	.0018	.00047	.00070	1.
26G	02-266	F	65238	391	7.0	46	0.12	0.81	42	1.9	0.070	.0086	.0019	.00035	.00040	1.
23E	01-265	M	65237	416	7.8	45	0.12	0.93	43	1.7	0.063	.0079	.0029	.00057	.0016	2.
24B	03-265	M	65237	398	8.2	42	0.15	1.2	44	1.6	0.059	.0055	.0024	.00074	.00074	2.
37F	01-282	F	65300	400	8.1	44	0.12	1.0	45	1.1	0.041	.0048	.0019	.00058	.00070	1.
24A	02-265	M	65237	398	8.0	40	0.16	1.3	46	1.0	0.037	.0047	.0017	.00038		1.
30E	01-276	M	65270	408	8.1	47	0.10	0.81	47	1.0	0.037	.0046	.0017	.00033	.00035	1.
30F	02-276	F	65270	408	10.4	48	0.10	1.0	48	0.97	0.036	.0043	.0013	.00031	.00036	1.

BETA RADIATION DOSE TO SKELETON

DOSE RATE (GY/DAY) INITIAL	730 DAYS	POTENT.AT 5000 DAYS	AT DEATH	CUMULATIVE (GY) 730 DAYS	POTENT.TO 5000 DAYS	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
.55	.21	.070	.21	180.	730. +	190.	69143	759	E-FIBROSARCOMA,PELVIS
.54		.013	.24		520. +	170.	68344	585	D-EPILEPTIC SEIZURES
.54	.16	.053	.15	140.	550. +	170.	69311	927	E-HEMANGIOSARCOMA,SITE UNDETERMINED
.48			.30			8.1	67296	21	D-HEMATOLOGICAL DYSCRASIA
.48			.34			11.	67303	28	D-HEMATOLOGICAL DYSCRASIA
.47	.21	.037	.20	180.	610. +	220.	69279	886	E-OSTEOSARCOMA,ILIUM
.47			.36			13.	67146	31	E-HEMATOLOGICAL DYSCRASIA
.45			.29			6.6	67135	18	E-HEMATOLOGICAL DYSCRASIA
.44	.18	.062	.17	150.	620. +	170.	69255	864	E-FIBROSARC.,RIBS;HEMANGIOSARC.,SCAPULA,RIB
.37	.15	.057	.14	130.	540. +	180.	68233	1099	E-OSTEOSARCOMA,RIB
.34			.25			8.5	67146	29	D-HEMATOLOGICAL DYSCRASIA
.31	.075	.032	.068	70.	280. +	99.	70163	1142	E-HEMANGIOSARCOMA,HUMERUS
.27	.081	.023	.059	76.	270. +	150.	70169	1737	E-OSTEOSARCOMA,HUMERUS
.24	.090	.037	.064	89.	330. +	180.	70343	1938	E-OST-SARC.,VERT.;HEM-SARC.,RIB AND MAND.
.23	.066	.019	.054	64.	220. +	100.	69023	1361	D-CEREBELLAR HEMORRHAGE
.26	.086	.045	.080	79.	350. +	100.	68074	1046	E-HEMANGIOSARCOMA,ILIUM
.23	.095	.023	.060	88.	320. +	170.	71363	1702	E-OSTEOSARCOMA,MAXILLA
.20	.047	.015	.024	47.	160. +	130.	74044	3122	E-OSTEOSARCOMA,VERTEBRAE
.19	.064	.024	.053	64.	230. +	100.	69173	1404	D-OSTEOSARCOMA,SACRUM
.18	.038	.013	.021	39.	140. +	100.	73243	2964	D-OSTEOSARCOMA,MAXILLA
.16	.062	.026	.051	59.	230. +	100.	69287	1540	E-OSTEOSARCOMA,MAXILLA
.13	.033	.014	.019	33.	120. +	95.	74151	3237	D-OSTEOSARCOMA,MANDIBLE
.12	.061	.015	.035	61.	200. +	130.	71258	2247	E-HEMANGIOSARCOMA,RIB
.12	.034	.013	.021	35.	120. +	85.	72279	2633	E-OSTEOSARCOMA,SKULL
.044	.015	.0061	.0068	15.	56. +	49.	76278	3994	E-HEPATITIS
.043	.014	.0056	.0084	15.	51. +	33.	72136	2436	D-MYELOMONOCYTIC LEUKEMIA
.042	.042	.0035	.0035	11.	37.	37.	80084	5261	E-MESOTHELIOMA, PLEURA
.040	.0081	.0025	.0025	8.4	28.	28.	81135	5678	E-OSTEOARTHRITIS
.037	.011	.0033	.0040	12.	39. +	38.	77327	4453	E-LYMPHOSARCOMA
.036	.0090	.0030	.0032	9.5	32.	32.	78304	4795	D-ADENOCARCINOMA,LUNG
.036	.011	.0030	.0030	11.	37.	37.	80263	5439	E-NEPHROSCLEROSIS
.032	.010	.0030	.0050	11.	35. +	28.	74046	3077	E-MYXOSARCOMA,MAXILLA
.031	.0088	.0031	.0031	9.3	31.	31.	80171	5440	D-CONGESTIVE HEART FAILURE
.030	.0091	.0028	.0039	9.3	32. +	29.	76114	3874	E-HEMANGIOSARCOMA,HEART
.028	.0083	.0028	.0033	8.3	30. +	27.	76211	3926	D-MALABSORPTION SYNDROME
.026	.0059	.0019	.0020	6.7	21.	21.	79253	5064	D-HEPATIC DEGENERATION
.015	.0041	.00077	.00090	4.1	13.	13.	79095	4970	E-TRANSITIONAL CELL CARCINOMA,BLADDER
.010	.0033	.0016	.0017	3.5	13. +	12.	78107	4584	D-CONGESTIVE HEART FAILURE
.010	.0037	.0012	.0013	3.8	13.	13.	79085	4927	E-ADENOCARCINOMA, NASAL CAVITY
.0098	.0019	.00035	.00039	1.9	5.7+	5.6	78235	4744	E-EPENDYMOMA,BRAIN
.0087	.0018	.00047	.00070	1.8	6.0+	5.3	75248	3662	E-PERITONITIS
.0086	.0019	.00035	.00040	1.8	5.8	5.8	79204	5079	E-ADENOCARCINOMA, MAMMARY GLAND
.0079	.0029	.00057	.0016	2.7	8.9+	6.1	71293	2247	D-ACCIDENTAL DEATH
.0055	.0024	.00074	.00074	2.2	8.3	8.3	80255	5496	E-NEPHROSCLEROSIS
.0048	.0019	.00058	.00070	1.9	6.6+	6.0	77034	4117	E-BRONCHIOLOALVEOLAR CARCINOMA
.0047	.0017	.00038		1.7	5.4	5.4	81341	5948	E-NEPHROSCLEROSIS
.0046	.0017	.00033	.00035	1.8	5.3+	4.3	74016	3033	D-TRANSITIONAL CELL CARCINOMA,BLADDER
.0043	.0013	.00031	.00036	1.4	4.3+	4.2	78228	4706	E-ADENOCARCINOMA,MAMMARY GLAND

2

A.1 $^{90}SrCl_2$, Longevity Study (continued)

DOG IDENTIFICATION			INHALATION EXP.			I.B.B.			L.T.R.B.			BETA RADIATION DOSE TO SKELE: DOSE RATE (GY/DAY)				CU
TATTOO	AN-EXPT	SEX	DATE	AGE DAYS	WT KG	RANK	MBQ/KG	MBQ	RANK	UCI/KG	MBQ/KG	INITIAL	730 DAYS	POTENT.AT 5000 DAYS	AT DEATH	730 DAYS
19A	01-254	M	65203	406	8.7	C			C							
21C	02-254	F	65203	398	8.5	C			C							
24E	01-264	F	65232	393	8.6	C			C							
26E	02-264	F	65232	385	6.9	C			C							
28A	01-273	M	65258	408	9.1	C			C							
30A	03-273	M	65258	396	9.5	C			C							
31A	01-278	M	65272	400	9.1	C			C							
32A	02-278	M	65272	394	8.9	C			C							
33B	03-278	M	65272	383	8.9	C			C							
35F	01-285	F	65305	414	8.1	C			C							
40D	02-285	F	65305	387	9.4	C			C							
42C	03-285	F	65305	380	10.3	C			C							
158A	01-420	M	67115	438	10.2	C			C							
160A	02-420	M	67117	437	9.9	C			C							
162E	03-420	F	67122	436	10.2	C			C							

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE INCL

1

BETA RADIATION DOSE TO SKELETON

	DOSE RATE (GY/DAY)			CUMULATIVE (GY)				DAYS	
L	730 DAYS	POTENT.AT 5000 DAYS	AT DEATH	730 DAYS	POTENT.TO 5000 DAYS	TO DEATH	DEATH DATE	TO DEATH	COMMENT
							73021	2740	D-SEPTICEMIA
							78057	4602	D-CONGESTIVE HEART FAILURE
							77357	4508	E-CARCINOMA,THYROID
							80157	5403	D-ASPIRATION PNEUMONIA
							80285	5505	D-CONGESTIVE HEART FAILURE
							75045	3439	E-EPIDERMAL CYST,SKULL
							74008	3023	D-ARTERIOSCLEROSIS;HYPOTHYROIDISM
							77125	4236	E-LYMPHOSARCOMA
							79262	5103	D-LYMPHOSARCOMA
							74030	3012	D-ACCIDENTAL DEATH
							75307	3654	D-ADENOCARCINOMA,MAMMARY GLAND
							79328	5136	D-NEPHROSCLEROSIS
							81009	5008	E-SQUAMOUS CELL CARCINOMA,TONSIL
							82120	5482	E-SQUAMOUS CELL CARCINOMA,TONSIL
							80141	4767	E-PITUITARY ADENOMA-CUSHING'S DISEASE

ATION EXPOSURE.

IVELY. PROMINENT FINDINGS ARE INCLUDED.

2

A.2 $^{90}SrCl_2$, Sacrifice Study

DOG IDENTIFICATION			INHALATION EXP.			I.B.B.			L.T.R.B.			BETA RADIATION DOSE TO SKELETON: DOSE RATE (GY/DAY)				CUMULATIV	
TATTOO	AN-EXPT	SEX	DATE	AGE DAYS	WT KG	RANK	MBQ/KG	MBQ	RANK	UCI/KG	MBQ/KG	INITIAL	730 DAYS	POTENT.AT 5000 DAYS	AT DEATH	730 DAYS	POTENT. 5000 DA
7B	01-212	M	65081	407	7.6	03	4.8	37	01	67	2.5	.29	.14	.030	.13	120	430+
4C	02-183	M	64325	405	7.4	02	4.8	36	02	65	2.4	.30			.23		
10A	02-215	M	65084	394	10.0	08	3.7	37	03	55	2.0	.22	.10	.022	.086	90	310+
8A	02-212	M	65081	402	7.9	01	5.5	44	04	51	1.9	.23	.10	.029	.084	90	340+
9D	01-215	F	65084	398	8.9	04	4.8	44	05	47	1.7	.20	.095	.026	.080	84	310+
11B	02-216	F	65085	389	9.7	09	3.4	33	06	47	1.7	.25			.17		
2B	01-183	M	64325	411	7.8	06	4.4	33	07	46	1.7	.21		.00001	.063		72+
10B	01-216	F	65085	395	7.9	10	3.2	26	08	44	1.6	.20	.071	.017	.046	63	220+
9B	01-214	M	65083	397	9.6	17	2.6	26	09	39	1.4	.18	.050	.0087	.038	48	150+
9C	02-214	F	65083	397	10.1	15	3.0	30	10	37	1.4	.17	.071	.010	.054	67	200+
12E	02-230	F	65125	403	8.4	18	2.6	21	11	36	1.3	.16	.060	.020	.039	56	210+
6B	01-207	M	65054	414	7.6	20	2.3	17	12	36	1.3	.13	.044	.019	.021	44	160+
5A	02-184	M	64328	391	9.2	07	4.1	37	13	35	1.3	.16		.00029	.072		96+
8B	01-213	M	65082	403	8.5	16	2.9	25	14	34	1.3	.16	.051	.017	.034	46	180+
4D	01-184	M	64328	408	9.2	11	3.1	29	15	31	1.1	.14			.11		
12B	01-229	F	65124	402	11.0	21	2.2	24	16	30	1.1	.13	.041	.012	.022	39	140+
6D	03-207	F	65054	414	7.4	13	3.0	22	17	29	1.1	.14	.043	.014	.024	43	150+
12D	01-230	F	65125	403	7.6	14	3.0	23	18	28	1.0	.13		.0034	.054		120+
6C	02-207	F	65054	414	8.2	19	2.4	20	19	24	0.89	.11	.040	.012	.017	38	130+
9A	02-213	M	65082	396	10.7	22	1.8	19	20	20	0.74	.093	.037	.014	.019	35	130+
4B	01-185	M	64329	409	8.8	23	1.7	15	21	16	0.59	.071	.029	.015	.019	28	110+
12C	02-229	F	65124	402	9.6	24	1.6	16	22	15	0.55	.068	.023	.0085	.0099	22	80+
2A	02-182	M	64324	410	6.8	05	4.4	30	23			.33			.27		
4A	01-182	M	64324	404	9.6	12	3.4	33	24						.13		
5C	03-182	F	64324	387	5.7	C			C								
2D	03-184	F	64328	414	9.9	C			C								
4E	03-183	F	64328	405	7.8	C			C								
6A	04-207	M	65054	414	10.0	C			C								
9E	01-217	F	65083	399	8.2	C			C								
10C	02-217	F	65085	393	8.9	C			C								
12A	01-231	M	65124	403	10.3	C			C								
13B	02-231	M	65124	383	9.6	C			C								
13C	03-231	M	65124	383	8.7	C			C								
13D	04-231	F	65124	383	6.5	C			C								

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE INCLUDED.

1

BETA RADIATION DOSE TO SKELETON

DOSE RATE (GY/DAY)			CUMULATIVE (GY)					
730 DAYS	POTENT.AT 5000 DAYS	AT DEATH	730 DAYS	POTENT.TO 5000 DAYS	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
.14	.030	.13	120	430+	150.	67279	928	E-HEMANGIOSARCOMA,SCAPULA
		.23			7.3	64353	28	S-
.10	.022	.086	90	310+	130.	68157	1168	E-HEMANGIOSARCOMA,SCAPULA
.10	.029	.084	90	340+	150.	68348	1362	E-OSTEOSARCOMA,VERTEBRA,SCAPULA
.095	.026	.080	84	310+	130.	68305	1316	E-HEMANGIOSARCOMA,THORAX; HUMERUS
		.17			6.0	65116	31	E-HEMATOLOGIC DYSCRASIA
	.00001	.063		72+	39.	65340	381	S-
.071	.017	.046	63	220+	140.	70293	2034	D-OSTEOSARC.,SCAPULA & RIB;HEMANGIOSARC.,RIB
.050	.0087	.038	48	150+	76.	68355	1367	E-FIBROSARCOMA,SKULL
.071	.010	.054	67	200+	100.	68306	1318	E-OSTEOSARC.,TIBIA;HEMANGIOSARC.,SITE UND.
.060	.020	.039	56	210+	140.	71314	2380	E-OSTEOSARCOMA,RIB,ILIUM
.044	.019	.021	44	160+	130.	75140	3738	E-SQUAMOUS CELL CARCINOMA, NASAL CAVITY
	.00029	.072		96+	36.	65341	379	S-
.051	.017	.034	46	180+	110.	71155	2264	E-OSTEOSARCOMA,TIBIA
		.11			3.5	64357	29	S-
.041	.012	.022	39	140+	100.	72336	2768	E-OSTEOSARCOMA,ILIUM
.043	.014	.024	43	150+	110.	72280	2782	E-OSTEOSARCOMA,MANDIBLE
	.0034	.054		120+	40.	66345	585	D-MYELOMONOCYTIC LEUKEMIA
.040	.012	.017	38	130+	110.	74239	3472	E-OSTEOSARCOMA,MANDIBLE
.037	.014	.019	35	130+	99.	74028	3233	E-OSTEOSARCOMA,MANDIBLE
.029	.015	.019	28	110+	71.	72035	2628	D-BASOSQUAMOUS CARCINOMA,TEMPORAL REGION
.023	.0085	.0099	22	80+	72.	76329	4222	E-SQUAMOUS CELL CARCINOMA, SINUS CAVITY
		.27			1.5	64329	5	S-
		.13			0.77	64329	5	S-
						64330	6	S-
						65342	380	S-
						64352	24	S-
						78044	4738	E-CARCINOMA,THYROID
						72165	2638	E-FIBROSARCOMA,THORACIC WALL
						75103	3670	D-ADENOCARCINOMA,LUNG
						78162	4786	D-CONGESTIVE HEART FAILURE; NEPHROSCLEROSIS
						72183	2615	D-AUTOIMMUNE HEMOLYTIC ANEMIA
						74147	3310	D-RENAL AMYLOIDOSIS
						79068	5057	E-ADENOCARCINOMA,MAMMARY GLAND

LATION EXPOSURE.

:TIVELY. PROMINENT FINDINGS ARE INCLUDED.

2

A.3 $^{144}CeCl_3$, Longevity Study

DOG IDENTIFICATION			INHALATION EXP.			I.B.B.	L.T.R.B.					BETA RADIATI[C] LUNG CUMULATIVE (GY)			CUMU[L]
TATTOO	AN-EXPT	SEX	DATE	AGE DAYS	WT KG	MBQ/KG	RANK	UCI/KG	UCI	MBQ/KG	MBQ	365 DAYS	730 DAYS	TO DEATH	365 DAYS
152C	02-407	F	67094	428	8.3	27.	01	360.	2900	13.	110.			210.	
156B	03-408	M	67096	418	8.6	19.	02	320.	2800	12.	100.			74.	
151B	01-407	M	67094	431	9.8	17.	03	270.	2700	10.	100.			76.	
156D	01-408	F	67096	418	10.0	16.	04	210.	2100	7.8	78.			48.	
198E	01-457	F	67278	392	8.7	15.	05	210.	1800	7.8	67.	170.		170.	280.
151C	03-407	F	67094	431	10.0	14.	06	190.	1900	7.0	70.			52.	
197D	02-458	F	67279	393	9.0	13.	07	190.	1700	7.0	63.			52.	
199A	02-462	M	67285	397	8.5	13.	08	190.	1600	7.0	59.			64.	
201G	02-463	F	67290	385	8.3	11.	09	170.	1400	6.3	52.			44.	
153A	02-408	M	67096	430	10.3	10.	10	150.	1500	5.5	56.			86.	
195A	01-458	M	67279	401	10.0	8.9	11	150.	1500	5.5	56.			120.	
198A	01-462	M	67285	399	8.5	11.	12	140.	1200	5.2	44.	110.	120.	120.	180.
203F	03-463	F	67290	377	6.3	13.	13	140.	870	5.2	32.			42.	
197C	03-462	M	67285	399	8.3	9.6	14	130.	1100	4.8	41.			98.	
200A	02-460	M	67283	390	10.2	7.0	15	120.	1300	4.4	48.	95.		100.	160.
199E	01-460	F	67283	395	7.5	12.	16	110.	810	4.1	30.	87.	97.	99.	150.
62F	02-322	F	66082	388	9.6	7.4	17	100.	960	3.7	36.	79.	88.	88.	130.
201C	03-460	M	67283	378	8.8	10.	18	94.	830	3.5	31.	74.	83.	85.	120.
64A	01-326	M	66096	391	9.0	8.1	19	74.	660	2.7	24.	58.	65.	67.	98.
60B	01-320	F	66075	402	8.6	4.8	20	69.	590	2.6	22.	55.	61.	62.	91.
200E	01-463	F	67290	397	8.3	9.3	21	68.	560	2.5	21.	54.	60.	61.	90.
62E	01-322	M	66082	388	8.1	4.8	22	67.	540	2.5	20.	53.	59.	60.	88.
64C	03-323	F	66084	379	9.3	5.2	23	55.	520	2.0	19.	43.	48.	50.	73.
62B	02-321	M	66080	386	9.9	4.1	24	51.	500	1.9	19.	40.	45.	46.	67.
63C	02-323	F	66084	383	6.8	6.3	25	44.	300	1.6	11.	35.	39.	39.	58.
66B	03-326	M	66096	385	8.8	4.4	26	43.	380	1.6	14.	34.	39.	39.	57.
65B	02-326	M	66096	386	10.9	4.1	27	39.	430	1.4	16.	31.	34.	35.	51.
61B	01-321	M	66080	397	9.5	2.5	28	31.	300	1.1	11.	24.	27.	28.	41.
60C	02-320	F	66075	402	10.2	4.8	29	28.	280	1.0	10.	22.	25.	25.	37.
63B	01-323	M	66084	383	8.1	4.8	30	26.	210	0.96	7.8	21.	23.	23.	34.
54A	01-305	M	66027	407	10.2	1.6	31	25.	250	0.93	9.3	20.	22.	23.	33.
54B	02-305	F	66027	407	11.6	1.6	32	24.	280	0.89	10.	19.	21.	22.	32.
52D	01-302	F	66025	410	7.7	1.6	33	21.	170	0.78	6.3	17.	18.	19.	28.
55D	02-306	F	66028	407	8.7	1.7	34	17.	150	0.63	5.5	13.	15.	15.	22.
60D	03-320	F	66075	402	8.8	5.5	35	16.	140	0.59	5.2	13.	14.	14.	21.
57A	02-308	M	66034	392	8.2	1.3	36	15.	130	0.55	4.8	12.	13.	14.	20.
53B	02-301	F	66024	404	11.0	1.6	37	14.	150	0.52	5.5	11.	12.	13.	18.
53C	02-302	F	66025	405	9.0	1.6	38	14.	130	0.52	4.8	11.	12.	13.	19.
56B	01-308	M	66034	402	10.9	1.3	39	14.	150	0.52	5.5	11.	12.	13.	19.
52C	01-301	F	66024	409	9.0	1.6	40	13.	120	0.48	4.4	10.	11.	12.	17.
55A	01-306	M	66028	407	10.8	1.2	41	12.	130	0.44	4.8	9.5	11.	11.	16.
57C	02-309	M	66035	393	8.2	0.89	42	12.	95	0.44	3.5	9.5	11.	11.	16.
51B	01-299	M	66021	408	8.4	0.52	43	8.1	68	0.30	2.5	6.4	7.1	7.3	11.
57B	01-309	M	66035	393	9.3	1.1	44	6.9	64	0.26	2.4	5.5	6.1	6.2	9.1
50E	03-297	F	66018	411	8.1	0.44	45	6.3	51	0.23	1.9	5.0	5.5	5.7	8.3
50A	01-297	M	66018	411	8.0	0.48	46	6.2	50	0.23	1.9	4.9	5.5	5.6	8.2
49A	01-294	M	66013	407	9.9	0.41	47	5.5	55	0.20	2.0	4.3	4.8	5.0	7.3
52B	02-299	M	66021	406	10.9	0.37	48	5.2	56	0.19	2.1	4.1	4.6	4.7	6.9
49B	02-294	M	66013	407	8.8	0.48	49	4.9	43	0.18	1.6	3.9	4.3	4.4	6.5

BETA RADIATION DOSE TO TISSUE

LUNG CUMULATIVE (GY)			LIVER CUMULATIVE (GY)			SKELETON CUMULATIVE (GY)					
65 AYS	730 DAYS	TO DEATH	365 DAYS	730 DAYS	TO DEATH	365 DAYS	730 DAYS	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
		210.			240.			70.	67238	144	D-PULMONARY INJURY
		74.			32.			9.6	67117	21	E-HEMATOLOGICAL DYSCRASIA
		76.			41.			12.	67125	31	E-HEMATOLOGICAL DYSCRASIA
		48.			21.			6.1	67118	22	E-HEMATOLOGICAL DYSCRASIA
0.		170.	280.		280.	82.		84.	68288	375	D-PULMONARY FIBROSIS
		52.			30.			8.6	67125	31	E-HEMATOLOGICAL DYSCRASIA
		52.			30.			8.6	67311	32	D-HEMATOLOGICAL DYSCRASIA
		64.			44.			13.	67329	44	D-HEMATOLOGICAL DYSCRASIA
		44.			22.			6.5	67317	27	D-HEMATOLOGICAL DYSCRASIA
		86.			96.			29.	67234	138	D-PULMONARY INJURY
		120.			190.			56.	68250	336	D-HEPATIC INJURY
).	120.	120.	180.	260.	270.	55.	78.	81.	69353	799	E-OSTEOSARCOMA,VERTEBRA
		42.			25.			7.4	67326	36	D-HEMATOLOGICAL DYSCRASIA
		98.			160.			46.	68229	309	D-HEPATIC INJURY
5.		100.	160.		190.	49.		58.	69062	510	D-MARROW APLASIA
7.	97.	99.	150.	200.	240.	43.	62.	74.	72265	1808	D-HEMANGIOSARCOMA,LIVER;HEPATIC DEGENERATION
9.	88.	88.	130.	190.	200.	39.	56.	60.	68226	874	D-HEPATIC INJURY
4.	83.	85.	120.	170.	210.	37.	53.	63.	72216	1759	E-HEMANGIOSARCOMA,LIVER;HEPATIC DEGENERATION
3.	65.	67.	98.	140.	160.	29.	41.	50.	72069	2164	E-SQUAMOUS CELL CARCINOMA,NASAL CAVITY
5.	61.	62.	91.	130.	150.	27.	39.	46.	70246	1632	E-SQUAM.CELL CARC.,NASAL CAVITY;ADENOMA,LUNG
4.	60.	61.	90.	130.	150.	27.	38.	46.	72247	1783	D-HEMANGIOSARCOMA,LIVER;HEPATIC DEGENERATION
3.	59.	60.	88.	120.	150.	26.	38.	45.	70356	1735	D-HEMANGIOSARCOMA,LIVER;HEPATIC FIBROMA
3.	48.	50.	73.	100.	120.	21.	31.	37.	71064	1806	E-MYELOGENOUS LEUKEMIA
).	45.	46.	67.	94.	110.	20.	29.	34.	72356	2467	D-HEMANGIOSARCOMA,LIVER;HEPATIC DEGENERATION
5.	39.	39.	58.	81.	97.	17.	29.	29.	78041	4340	E-BILE DUCT CYSTADENOMA,MULTIPLE;HEPATIC DEGEN.
4.	39.	39.	57.	80.	95.	17.	29.	29.	73312	2773	E-SQUAM.CELL CARC.,NASAL CAVITY;CARCINOMA,LUNG
1.	34.	35.	51.	72.	86.	15.	22.	26.	73151	2612	E-HEMANGIOSARCOMA,NASAL CAVITY
4.	27.	28.	41.	57.	68.	12.	21.	21.	75287	3494	D-SQUAMOUS CELL CARCINOMA,NASAL CAVITY
2.	25.	25.	37.	52.	62.	11.	19.	19.	75093	3305	E-MALIGNANT MELANOMA,EAR CANAL; EPENDYMOMA
1.	23.	23.	34.	48.	57.	10.	17.	17.	78326	4625	E-SQ. CELL CARC.,MOUTH;BILE DUCT CYSTADENOMAS,MULT.
).	22.	23.	33.	46.	55.	9.8	17.	17.	78354	4710	E-NEPHRITIS, BILIARY CYSTS,MULT.;CARC.,PROSTATE
).	21.	22.	32.	44.	53.	9.4	16.	16.	76351	3976	E-CARCINOMA,MAMMARY GLAND;NODULAR HYPERPLASIA LIVER
7.	18.	19.	28.	39.	46.	8.2	14.	14.	80051	5139	E-CARCINOMA,BLADDER;CARC.,LUNG;CARC.,THYROID
.	15.	15.	22.	31.	37.	6.6	11.	11.	77062	4052	E-DISC DISEASE;CARC.,THYR. AND ADREN.;BILIARY CYSTS
5.	14.	14.	21.	30.	35.	6.2	11.	11.	77251	4194	E-HEMANGIOSAR.,LIV.;BILIARY CYSTS,MULT.;ADENOMA,PIT.
2.	13.	14.	20.	28.	33.	5.9	8.4	10.	71034	1826	E-MYELOPROLIFERATIVE DISORDER
.	12.	13.	18.	26.	31.	5.5	9.4	9.4	77064	4058	D-CONGESTIVE HEART FAILURE
.	12.	13.	19.	26.	31.	5.5	7.8	9.4	78116	4474	E-CARC.,MAM.GLAND;BILE DUCT CYSTADENOMA;HEP. DEGEN.
.	12.	13.	19.	26.	31.	5.5	7.8	9.4	71019	1811	D-MYELOGENOUS LEUKEMIA
).	11.	12.	17.	24.	29.	5.1	7.3	8.7	75298	3561	D-ADENOCARC.,MAM.GLAND;SQUA.CELL CARC.,NASAL CAVITY
).5	11.	11.	16.	22.	26.	4.7	6.7	8.0	76070	3694	E-ADENOCARC.,BRONCHOGENIC-LUNG;BILIARY CYSTAD.,MULT.
).5	11.	11.	16.	22.	26.	4.7	6.7	8.0	77102	4085	E-SQUAM.CELL CARC.,NASAL CAVITY
.4	7.1	7.3	11.	15.	18.	3.2	4.5	5.4	81027	5485	E-CARCINOMA,LIVER-HEPATOCELLULAR
.5	6.1	6.2	9.1	13.	15.	2.7	3.9	4.6	80059	5137	D-CARCINOMA,BILE DUCT
.0	5.5	5.7	8.3	12.	14.	2.5	3.5	4.2	74213	3117	D-HEPATIC LIPIDOSIS & DEGENERATION
.9	5.5	5.6	8.2	12.	14.	2.4	3.5	4.2	74031	2935	D-EPENDYMOMA, CENTRAL NERVOUS SYSTEM
.3	4.8	5.0	7.3	10.	12.	2.2	3.1	3.7	78012	4382	D-MALIGNANT MELANOMA,SOFT PALATE
.1	4.6	4.7	6.9	9.6	11.	2.0	2.9	3.5	78279	4641	E-ADENOCARCINOMA, PERIANAL GLAND
.9	4.3	4.4	6.5	9.1	11.	1.9	2.7	3.3	80020	5120	D-HEPAT.NOD.HYPERPLASIA;CARC.,THYR.;ASPIRATION PNEU.

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A.3 $^{144}CeCl_3$, Longevity Study (continued)

DOG IDENTIFICATION			INHALATION EXP.			I.B.B.	I.T.R.B.					BETA RADIATION DOSE TO TIS					
												LUNG CUMULATIVE (GY)			LIVER CUMULATIVE (GY)		
TATTOO	AN-EXPT	SEX	DATE	AGE DAYS	WT KG	MBQ/KG	RANK	UCI/KG	UCI	MBQ/KG	MBQ	365 DAYS	730 DAYS	TO DEATH	365 DAYS	730 DAYS	TO DEATH
49D	01-295	F	66014	408	10.9	0.41	50	4.7	52	0.17	1.9	3.7	4.1	4.2	6.2	8.7	10.
50F	01-298	F	66020	413	8.3	0.48	51	4.2	35	0.16	1.3	3.3	3.7	3.8	5.5	7.8	9.2
49E	02-295	F	66014	408	9.1	0.37	52	3.9	36	0.14	1.3	3.1	3.4	3.5	5.2	7.2	8.6
51A	02-298	M	66020	407	11.1	0.32	53	3.6	40	0.13	1.5	2.8	3.2	3.2	4.8	6.7	7.9
50D	02-297	F	66018	411	6.9	0.48	54	2.0	20	0.11	0.74	2.3	2.6	2.6	3.8	5.4	6.4
49G	01-296	F	66017	411	8.4	0.28	55	2.6	22	0.096	0.81	2.1	2.3	2.3	3.4	4.8	5.7
49C	01-300	M	66013	407	8.7		C										
50C	02-300	F	66017	414	9.1		C										
51C	03-300	M	66021	408	10.4		C										
51E	04-300	F	66021	408	8.4		C										
52A	05-300	M	66021	406	8.5		C										
53A	01-310	F	66024	415	9.3		C										
53D	02-310	F	66024	415	8.1		C										
54C	03-310	F	66027	415	9.2		C										
56A	04-310	M	66034	403	11.8		C										
60A	01-327	M	66075	402	10.1		C										
61C	02-327	F	66080	397	10.0		C										
62A	03-327	M	66080	386	13.2		C										
153D	01-412	F	67094	437	9.3		C										
156E	02-412	F	67094	425	6.7		C										
197B	01-465	M	67289	410	9.0		C										
198C	02-465	F	67289	410	9.9		C										
201A	03-465	M	67289	391	12.6		C										

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE INCLU

BETA RADIATION DOSE TO TISSUE

GY)	LIVER CUMULATIVE (GY)			SKELETON CUMULATIVE (GY)					
TO DEATH	365 DAYS	730 DAYS	TO DEATH	365 DAYS	730 DAYS	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
4.2	6.2	8.7	10.	1.8	2.6	3.1	79144	4878	E-HEMANGIOSAR.,LIVER;CARC.ADREN.;MULT. BILIARY CYSTS
3.8	5.5	7.8	9.2	1.6	2.4	2.8	74038	2940	D-MYELOMALACIA
3.5	5.2	7.2	8.6	1.5	2.2	2.6	75213	3486	D-PULMONARY EDEMA;NODULAR HYPERPLASIA,LIVER
3.2	4.8	6.7	7.9	1.4	2.0	2.4	74309	3211	D-CONGESTIVE HEART FAILURE;HEPATIC DEGENERATION
2.6	3.8	5.4	6.4	1.1	1.6	1.9	76358	3992	D-CONG.HEART FAILURE;CHRONIC NEPHRITIS;ADENOMA,MAM.
2.3	3.4	4.8	5.7	1.0	1.5	1.7	81036	5498	D-CARCINOMA,PANCREAS;CARCINOMA MAMMARY
							74156	3065	D-ASPIRATION PNEUMONIA,EPILEPSY
							81273	5735	E-RENAL CORTICAL ATROPHY
							76103	3734	D-ANESTHETIC DEATH;HEPATIC DEGENERATION
							79337	5064	E-CARCINOMA,MAMMARY;NEUROFIBROSARCOMA,SUBCUTIS
							76189	3820	D-RENAL AMYLOIDOSIS; UREMIA
							79019	4743	E-CARCINOMA,THYROID;OVARIAN TUMOR
							78073	4432	E-MYELOMALACIA
							80106	5192	E-CARCINOMA,ADRENAL
							80037	5116	E-CARC,LUNG;OLF.NEUROBLASTOMA;SQ.CELL CARC,SAL.GLAND
							82205	5974	D-RENAL ATROPHY AND FIBROSIS
							80333	5366	D-ASPIR.PNEUM.;ADENOCARC.,LUNG;CARC.THY.;CAR.MAMMARY
							73068	2545	E-CARCINOMA,THYROID
							67243	149	S-
							67243	149	S-
							84096	6016	D-VALVULAR INSUFFICIENCY,HEART
							79044	4138	E-MAST CELL TUMOR,SUBCUTIS
							82314	5895	E-INTERSTITIAL NEPHRITIS

SURE.

MINENT FINDINGS ARE INCLUDED.

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(1)

A.4 $^{91}YCl_3$, Longevity Study

DOG IDENTIFICATION			INHALATION EXP.			I.B.B.	L.T.R.B.					BETA RADIATION DOSE TO TISSUE						
												LUNG CUMULATIVE (GY)			LIVER CUMULATIVE (GY)			CU
TATTOO	AN-EXPT	SEX	DATE	AGE DAYS	WT KG	MBQ/KG	RANK	UCI/KG	UCI	MBQ/KG	MBQ	365 DAYS	730 DAYS	TO DEATH	365 DAYS	730 DAYS	TO DEATH	365 DAY
118E	02-380	F	66320	413	9.3	48.	01	540	5100	20.	190.			43.			3.4	
122C	01-383	M	66333	410	9.8	28.	02	300	3000	11.	110.			28.			3.0	
118F	01-382	F	66326	419	8.0	29.	03	290	2300	11.	85.			25.			2.5	
119C	01-384	F	66335	423	8.2	20.	04	250	2100	9.3	78.			24.			2.7	
164B	01-423	M	67146	409	9.5	16.	05	250	2300	9.3	85.			24.			2.7	
119D	02-382	F	66326	414	6.5	27.	06	240	1600	8.9	59.			25.			3.2	
123A	02-383	M	66333	409	11.0	33.	07	240	2600	8.9	96.			23.			2.5	
118A	01-381	M	66322	415	8.1	20.	08	220	1800	8.1	67.	24.	30.	33.	3.1	8.1	10.	8.4
119A	03-381	M	66322	409	8.3	20.	09	220	1800	8.1	67.	24.	30.	33.	3.1	8.1	10.	8.4
118D	02-381	F	66322	415	8.6	19.	10	200	1800	7.4	67.	22.	28.	31.	2.8	7.0	9.7	7.6
120C	03-384	F	66335	420	9.3	23.	11	200	1900	7.4	70.			20.			2.3	
164F	02-423	F	67146	409	9.0	17.	12	200	1800	7.4	67.			20.			2.3	
165A	01-426	M	67153	392	11.0	20.	13	160	1700	5.9	63.	18.	23.	24.	2.3	5.9	7.6	6.1
171F	02-434	F	67163	391	6.3	26.	14	160	1000	5.9	37.	18.	23.	24.	2.3	5.9	7.6	6.1
169C	01-434	M	67163	397	8.7	17.	15	150	1300	5.5	48.	17.	22.	23.	2.1	5.4	7.0	5.7
118B	01-380	M	66320	413	7.9	13.	16	140	1100	5.2	41.	15.	19.	20.	1.9	5.1	6.5	5.3
120A	02-384	M	66335	420	10.6	20.	17	130	1400	4.8	52.	14.	18.	20.	1.8	4.7	5.9	4.9
164C	03-422	M	67144	407	9.3	10.	18	110	1100	4.1	41.	12.	15.	17.	1.6	4.0	5.2	4.2
169D	01-432	F	67159	393	5.9	5.2	19	100	610	3.7	23.	11.	14.	15.	1.4	3.6	4.8	3.8
164G	01-425	F	67151	414	7.7	6.3	20	94	730	3.5	27.	10.	13.	14.	1.3	3.4	4.5	3.6
174A	01-438	M	67172	385	9.6	7.0	21	92	880	3.4	33.	10.	13.	14.	1.3	3.3	4.4	3.5
171B	02-435	M	67153	394	9.0	8.5	22	90	820	3.3	30.	9.8	13.	14.	1.2	3.2	4.3	3.4
165F	03-426	F	67153	392	9.2	8.1	23	82	750	3.0	28.	9.0	11.	12.	1.1	3.0	3.9	3.1
166E	02-426	F	67153	390	11.1	15.	24	73	820	2.7	30.	8.0	10.	11.	1.0	2.6	3.5	2.8
172A	03-435	M	67166	385	8.8	6.7	25	68	600	2.5	22.	7.4	9.5	10.	0.97	2.5	3.5	2.6
134C	02-385	F	66354	408	9.9	8.5	26	66	650	2.4	24.	7.2	9.3	10.	0.92	2.4	3.1	2.5
134A	01-385	M	66354	408	9.7	8.5	27	62	600	2.3	22.	6.7	8.6	9.4	0.86	2.3	3.0	2.4
176D	03-438	F	67172	384	9.2	9.3	28	60	550	2.2	20.	6.6	8.4	9.1	0.86	2.2	2.9	2.3
169A	01-435	M	67166	400	10.3	8.9	29	58	600	2.1	22.	6.4	8.1	8.9	0.81	2.1	2.8	2.2
172C	01-433	F	67160	379	7.1	4.4	30	53	380	2.0	14.	5.8	7.4	8.1	0.76	1.9	2.5	2.0
173G	02-433	F	67160	376	7.2	4.8	31	52	370	1.9	14.	5.7	7.2	7.9	0.76	1.9	2.5	2.0
174E	02-438	F	67172	385	8.7	7.4	32	51	450	1.9	17.	5.6	7.1	7.7	0.70	1.8	2.4	1.9
167B	01-431	M	67158	394	10.5	4.8	33	51	540	1.9	20.	5.6	7.1	7.7	0.70	1.8	2.4	1.9
171E	03-429	F	67156	384	6.4	5.2	34	48	310	1.8	11.	5.2	6.7	7.4	0.65	1.7	2.3	1.8
165G	02-422	F	67144	383	8.2	3.4	35	46	380	1.7	14.	5.1	6.5	7.0	0.65	1.7	0.20	1.7
169B	01-429	M	67156	390	9.9	3.0	36	44	440	1.6	16.	4.8	6.1	6.7	0.59	1.6	2.1	1.7
164D	01-422	M	67144	407	9.3	4.8	37	43	400	1.6	15.	4.7	6.0	6.6	0.59	1.6	2.1	1.6
176E	01-437	F	67170	382	6.8	5.5	38	41	280	1.5	10.	4.4	5.7	6.2	0.59	1.5	1.9	1.6
171A	02-429	M	67156	384	8.2	3.5	39	40	320	1.5	12.	4.3	5.6	6.1	0.54	1.5	1.9	1.5
166C	02-425	M	67151	388	11.0	2.4	40	31	350	1.1	13.	3.4	4.3	4.7	0.44	1.1	1.5	1.2
174F	02-437	F	67170	381	6.2	3.1	41	16	97	0.59	3.6	1.8	2.3	2.4	0.23	0.59	0.76	0.61
167C	04-426	M	67153	389	9.9	2.4	42	14	140	0.52	5.2	1.5	1.9	2.2	0.19	0.51	0.65	0.53
118C	01-386	F	66320	447	10.2		C											
119B	02-386	M	66322	442	9.4		C											
121A	04-386	M	66335	435	9.4		C											
164E	01-430	F	67151	20	8.8		C											
165D	02-430	M	67151	396	11.4		C											
165E	03-430	F	67151	[illegible]	9.0		C											
166B	04-430	M	67153	39[illegible]	10.3		C											
167A	01-441	M	67156	[illegible]	10.3		C											
167E	02-441	F	67156	413	10.3		C											
171D	03-441	F	67163	405	7.8		C											
174D	04-441	F	67166	390	13.1		C											
176B	05-441	M	67195	389	10.4		C											

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABECQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE INCLUDE

(2)

TA RADIATION DOSE TO TISSUE

LIVER CUMULATIVE (GY) 365 DAYS	730 DAYS	TO DEATH	SKELETON C MULATIVE (GY) 365 DAYS	730 DAYS	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
		3.4			9.1	66332	12	D-HEMATOLOGICAL DYSCRASIA
		3.0			8.0	66353	20	D-HEMATOLOGICAL DYSCRASIA
		2.5			6.7	66343	17	E-HEMATOLOGICAL DYSCRASIA
		2.7			7.3	66357	22	D-HEMATOLOGICAL DYSCRASIA
		2.7			7.3	67168	22	D-HEMATOLOGICAL DYSCRASIA
		3.2			8.6	66354	28	D-HEMATOLOGICAL DYSCRASIA
		2.5			6.7	66354	21	D-HEMATOLOGICAL DYSCRASIA
3.1	8.1	10.	8.4	21.	29.	72143	2012	E-SQUAMOUS CELL CARCINOMA, NASAL CAVITY
3.1	8.1	10.	8.4	21.	29.	79137	4563	E-HEPATIC FIBROSIS
2.8	7.0	9.7	7.6	19.	26.	79097	4523	D-CARCINOMA,MAMMARY GLAND
		2.3			6.0	66358	23	E-HEMATOLOGICAL DYSCRASIA
		2.3			6.2	67170	24	D-HEMATOLOGICAL DYSCRASIA
2.3	5.9	7.6	6.1	15.	21.	79074	4304	D-CONGESTIVE HEART FAILURE
2.3	5.9	7.6	6.1	15.	21.	74173	2567	E-SQUAMOUS CELL CARCINOMA, NASAL CAVITY
2.1	5.4	7.0	5.7	14.	20.	77202	3692	E-LYMPHOMA, VISCERA
1.9	5.1	6.5	5.3	13.	18.	78261	4324	E-RIGHT HEART FAILURE
1.8	4.7	5.9	4.9	12.	17.	78038	4086	E-NEPHROSCLEROSIS
1.6	4.0	5.2	4.2	11.	14.	68252	473	D-EPILEPTIC SEIZURE
1.4	3.6	4.8	3.8	9.6	13.	80344	4933	E-CONGESTIVE HEART FAILURE
1.3	3.4	4.5	3.6	9.0	12.	73217	2258	D-SARCOMA, MAST CELL
1.3	3.3	4.4	3.5	8.8	12.	79061	4272	D-CARCINOMA,LUNG
1.2	3.2	4.3	3.4	8.6	12.	79114	4344	E-UREMIA
1.1	3.0	3.9	3.1	7.9	11.	80032	4627	D-HEMANGIOSARCOMA,LIVER
1.0	2.6	3.5	2.8	7.0	9.5	81065	5026	D-DISSEMINATED CARCINOMA
0.97	2.5	3.5	2.6	6.5	8.8	82085	5398	E-PROSTATITIS
0.92	2.4	3.1	2.5	6.3	8.6	76054	3352	E-SQ.CELL CARC,NASAL CAV.;HEM.SARC.,UNDET.SITE
0.86	2.3	3.0	2.4	6.0	8.1	81007	5132	D-CONGESTIVE HEART FAILURE
0.86	2.2	2.9	2.3	5.8	7.8	79356	4567	D-PULMONARY INFARCTION
0.81	2.1	2.8	2.2	5.6	7.5	68165	364	D-EPILEPTIC SEIZURE
0.76	1.9	2.5	2.0	5.1	6.9	78257	4115	E-CHEMODECTOMA
0.76	1.9	2.5	2.0	5.0	6.8	80134	4722	E-CARCINOMA,MAMMARY GLAND
0.70	1.8	2.4	1.9	4.9	6.6	81175	5117	D-RENAL FAILURE
0.70	1.8	2.4	1.9	4.9	6.6	83066	5752	E-CARCINOMA,ORAL CAVITY
0.65	1.7	2.3	1.8	4.6	6.2	77117	3614	D-DISSEMINATED CARCINOMA,MAMMARY GLAND
0.65	1.7	0.20	1.7	4.4	6.0	78223	4097	E-AMELOANOTIC MELANOSARCOMA, MOUTH
0.59	1.6	2.1	1.7	4.2	5.7	78025	3887	D-AUTOIMMUNE HEMOLYTIC ANEMIA
0.59	1.6	2.1	1.6	4.1	5.6	82300	5635	D-ENTERITIS
0.59	1.5	1.9	1.6	3.9	5.3	80288	4866	E-LEIOMYOMA, VAGINA
0.54	1.5	1.9	1.5	3.8	5.2	79165	4392	E-RENAL FAILURE
0.44	1.1	1.5	1.2	3.0	4.0	79172	4404	D-CELLUTITIS
0.23	0.59	0.76	0.61	1.5	2.1	74276	2663	D-GLOMERULONEPHRITIS; RENAL FAILURE
0.19	0.51	0.65	0.53	1.3	1.8	81160	5121	D-BRONCHOPNEUMONIA
						81296	5455	E-ADENOCARCINOMA,MAMMARY GLAND
						80024	4815	E-CARCINOMA,THYROID
						81132	5276	E-OSTEOARTHRITIS
						77203	3705	E-DISSEMINATED CARCINOMA,MAMMARY GLAND
						79134	4366	E-HEMANGIOSARCOMA,LIVER
						78279	4146	D-HEPATIC DEGENERATION
						81195	5156	E-HEMANGIOSARCOMA,PERITONEUM
						73205	2241	D-SUPPURATIVE PLEURITIS
						81226	5184	E-CARCINOMA,STOMACH
						78187	4042	D-CONGESTIVE HEART FAILURE
						78107	3959	E-GASTROENTERITIS
						81190	5109	D-INTERSTITIAL NEPHRITIS

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4INENT FINDINGS ARE INCLUDED.

A.5 $^{91}YCl_3$, Sacrifice Study

DOG IDENTIFICATION			INHALATION EXP.			I.B.B.	I.L.B.					BETA RADIATION DOSE TO TISSUE: LUNG CUMULATIVE (GY)			LIVER CUMULATIVE (GY)			SKEL CUMULAT	
TATTOO	AN-EXPT	SEX	DATE	AGE DAYS	WT KG	MBQ/KG	RANK	UCI/KG	UCI	MBQ/KG	MBQ	30 DAYS	120 DAYS	TO DEATH	30 DAYS	120 DAYS	TO DEATH	30 DAYS	12 DA
173F	02-442	F	67179	395	9.1	9.6	01	220	1000	8.1	37	24	30	33	5.7	15	19.	8.4	2
172B	01-442	M	67179	398	7.2	19.	02	220	1600	8.1	59			23			5.3		
176C	01-443	F	67180	392	8.3	14.	03	170	1500	6.3	56	19		19	4.4		4.8	6.5	
174C	02-443	M	67180	393	7.9	11.	04	120	970	4.4	36	13	17	18	3.1	8	11.	4.6	1

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE INCLUDED.

(1)

RADIATION DOSE TO TISSUE

LIVER CUMULATIVE (GY)			SKELETON CUMULATIVE (GY)					
30 DAYS	120 DAYS	TO DEATH	30 DAYS	120 DAYS	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
5.7	15	19.	8.4	21	29.	73096	2109	D-BRONCHIOLOALVEOLAR CARCINOMA;CARCINOMA,MAMMARY
		5.3			7.5	67206	27	D HEMATOLOGICAL DYSCRASIA
4.4		4.8	6.5		6.8	67213	33	D-HEMATOLOGICAL DYSCRASIA
3.1	8	11.	4.6	12	16.	81021	4955	E-ENCEPHALOPATHY

:URE.

:MINENT FINDINGS ARE INCLUDED.

2

A.6 $^{137}CsCl$, Longevity Study

DOG IDENTIFICATION		INJECTION EXPOSURE					I.B.B.					BETA RADIATION DO[SE]				
												DOSE RATE (GY/DAY)				
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	30 DAYS	180 DAYS	365 DAYS	DI
271D	12-558	F	F	68330	421	7.2	01	4000	29000	150	1100	.72				.3
244B	06-522	M	A	68164	402	8.8	02	3900	34000	140	1300	.72	.31			.3
241F	06-523	F	B	68165	419	8.2	03	3900	32000	140	1200	.71				.3
273A	11-558	M	E	68330	405	9.4	04	3800	36000	140	1300	.69				.4
249D	06-540	M	D	68215	422	10.1	05	3600	36000	130	1300	.68				.3
253C	06-539	F	C	68214	393	9.5	06	3500	33000	130	1200	.65				.3
277F	09-560	F	H	68354	392	7.1	07	3000	21000	110	780	.54	.19	.0020	.00002	
284B	09-562	M	I	69028	394	8.5	08	2900	25000	110	930	.52	.18	.0020	.00001	
282C	10-562	F	J	69028	402	7.6	09	2900	22000	110	810	.53	.25	.0059	.00020	
280C	09-567	F	L	69052	429	7.9	10	2900	23000	110	850	.53				.3
292A	10-567	M	K	69052	377	8.5	11	2900	25000	110	930	.52	.17	.0030	.00003	
241G	05-523	F	B	68165	419	8.6	12	2800	24000	100	890	.51				.2
247E	05-539	F	C	68214	428	7.9	13	2800	22000	100	810	.51				.2
266C	09-558	M	E	68330	435	7.4	14	2800	21000	100	780	.50	.23	.0025	.00005	
273E	10-558	F	F	68330	405	8.3	15	2800	23000	100	850	.51	.26	.0075	.00030	
245B	05-522	M	A	68164	392	9.1	16	2700	25000	100	930	.51	.18			.0
279D	10-560	M	G	68354	383	8.1	17	2700	22000	100	810	.48	.22	.0050	.00010	
248A	05-540	M	D	68215	428	9.6	18	2600	25000	96	930	.48	.23	.0030	.00003	
244E	04-523	F	B	68165	403	7.5	19	2100	16000	78	590	.37	.16	.0035	.00004	
266D	08-558	F	F	68330	435	7.8	20	2100	16000	78	590	.37	.15	.0020	.00005	
279B	07-560	M	G	68354	383	9.9	21	2000	20000	74	740	.36	.19	.0060	.00020	
275E	08-560	F	H	68354	410	7.8	22	2000	16000	74	590	.37	.15	.0020	.00003	
283D	08-562	F	J	69028	423	8.8	23	2000	18000	74	670	.37	.13	.0025	.00004	
292C	08-567	F	L	69052	377	9.0	24	1900	17000	70	630	.36	.14	.0040	.00008	
241A	04-522	M	A	68164	418	10.0	25	1900	19000	70	700	.36	.18			.0
271A	07-558	M	E	68330	421	9.8	26	1900	19000	70	700	.35	.19	.0040	.00010	.0
283A	07-562	M	I	69028	423	11.2	27	1900	21000	70	780	.35	.14	.0030	.00005	
291A	07-567	M	K	69052	382	10.8	28	1900	21000	70	780	.35	.12	.0028	.00003	
253B	04-539	F	C	68214	393	9.7	29	1800	17000	67	630	.34	.15	.0040	.00006	
247A	04-540	M	D	68215	429	9.8	30	1800	18000	67	670	.34	.17	.0060	.00010	
244C	03-522	M	A	68164	402	6.7	31	1600	11000	59	410	.28	.090	.0013	.00001	
280D	06-562	F	J	69028	405	6.8	32	1600	11000	59	410	.28	.098	.0025	.00003	
279A	05-560	M	G	68354	383	9.5	33	1500	14000	56	520	.27	.11	.0011	.00002	
278F	06-560	F	H	68354	391	8.4	34	1500	13000	56	480	.26	.13	.0030	.00010	
286D	05-567	F	L	69052	417	8.8	35	1500	13000	56	480	.27	.10	.0022	.00004	
241E	03-523	F	B	68165	419	9.4	36	1400	13000	52	480	.26	.14	.0050	.00015	
267A	05-558	M	E	68330	435	11.2	37	1400	16000	52	590	.26	.15	.0060	.00020	
268C	06-558	F	F	68330	433	11.0	38	1400	15000	52	560	.26	.17	.014	.00060	
289D	05-562	M	I	69028	376	9.7	39	1400	14000	52	520	.26	.099	.0030	.00005	
247C	03-540	M	D	68215	429	8.8	40	1300	11000	48	410	.25	.12	.0018	.00003	
291C	06-567	M	K	69052	382	7.7	41	1200	9200	44	340	.22	.11	.0041	.00005	
252C	03-539	F	C	68214	407	9.3	42	1200	11000	44	410	.21	.12	.0025	.00005	
244F	02-523	F	B	68165	403	5.8	43	1100	6400	41	240	.20	.072	.00083	.00001	
278B	04-560	M	G	68354	391	9.5	44	1100	10000	41	370	.21	.10	.0020	.00003	
241B	02-522	M	A	68164	418	9.8	45	1000	9800	37	360	.19	.079	.0013	.00001	
273F	04-558	F	F	68330	405	8.4	46	1000	8400	37	310	.19	.10	.0045	.00040	
278D	03-560	F	H	68354	391	10.3	47	1000	10000	37	370	.19	.084	.0013	.00004	
281C	04-562	F	J	69028	404	8.4	48	1000	8400	37	310	.19	.065	.0015	.00006	
281B	03-567	F	L	69052	428	9.8	49	940	9200	35	340	.17	.081	.0030	.00008	

BETA RADIATION DOSE TO WHOLE BODY

	DOSE RATE (GY/DAY)				CUMULATIVE (GY)						
IAL	30 DAYS	180 DAYS	365 DAYS	AT DEATH	30 DAYS	180 DAYS	365 DAYS	AT DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
2				.31				11.	68356	26	D-HEMATOLOGICAL DYSCRASIA
2	.31			.30	13.			14.	68197	33	D-HEMATOLOGICAL DYSCRASIA
1				.38				10.	68187	22	D-HEMATOLOGICAL DYSCRASIA
9				.43				9.5	68349	19	D-HEMATOLOGICAL DYSCRASIA
8				.35				13.	68242	27	D-HEMATOLOGICAL DYSCRASIA
5				.38				9.7	68236	22	D-HEMATOLOGICAL DYSCRASIA
4	.19	.0020	.00002		9.2	15.	15.	15.	80094	4123	E-RENAL INFARCTION
2	.18	.0020	.00001		9.0	15.	15.	15.	81182	4537	D-CARCINOMA,PROSTATE
3	.25	.0059	.00020		10.	20.	20.	20.	73271	1704	E-ARTHRITIS;PNEUMONIA
3				.32				9.1	69076	24	E-HEMATOLOGICAL DYSCRASIA
2	.17	.0030	.00003		7.9	15.	15.	15.	81146	4477	E-CARC.,NASAL CAVITY;CARC.,INTESTINE
1				.27				8.6	68190	25	D-HEMATOLOGICAL DYSCRASIA
1				.27				9.1	68241	27	D-HEMATOLOGICAL DYSCRASIA
0	.23	.0025	.00005		9.5	17.	17.	17.	73097	1594	D-PNEUMONIA;PHARYNGITIS
1	.26	.0075	.00030		10.	22.	22.	22.	77343	3301	E-SUPPURATIVE ENDOMETRITIS
1	.18			.051	8.6			14.	68245	81	D-HEMATOLOGICAL DYSCRASIA
8	.22	.0050	.00010		9.5	18.	18.	18.	76139	2707	E-SARCOMA, MAST CELL
8	.23	.0030	.00003		10.	19.	19.	19.	77313	3386	E-SQUAM. CELL CARCINOMA,SINUS CAVITY
7	.16	.0035	.00004		7.0	15.	15.	15.	80022	4240	E-NEPHROSCLEROSIS;CARCINOMA, LUNG
7	.15	.0020	.00005		6.7	12.	12.	12.	77204	3162	D-CONGESTIVE HEART FAILURE
6	.19	.0060	.00020		7.8	15.	15.	15.	79262	3926	E-TUMOR, PERIPHERAL NERVE
7	.15	.0020	.00003		7.0	12.	12.	12.	83013	5138	D-MAMMARY ADENOCARCINOMA
7	.13	.0025	.00004		6.4	11.	11.	11.	80322	4311	D-HEMATOMA,SPLEEN
6	.14	.0040	.00008		6.7	12.	12.	12.	77277	3147	D-HEMANGIOSARCOMA,HEART
6	.18			.090	7.1			13.	68241	77	D-HEMATOLOGICAL DYSCRASIA
5	.19	.0040	.00010	.000003	7.3	15.	15.	15.	70292	693	D-SHOCK
5	.14	.0030	.00005		7.3	12.	12.	12.	80286	4275	D-HEMANGIOSARCOMA,SPLEEN
5	.12	.0028	.00003		6.3	10.	10.	10.	80077	4042	E-LEUKOENCEPHALOMALACIA
4	.15	.0040	.00006		6.5	13.	13.	13.	80265	4434	D-CARCINO[illegible] MAMMARY GLAND
4	.17	.0060	.00010		7.2	15.	15.	15.	80280	4448	D-HEPATIC DEGENERATION
8	.090	.0013	.00001		4.3	7.7	7.7	7.7	82091	5041	D-HEPATIC ATROPHY
8	.098	.0025	.00003		5.0	8.4	8.5	8.5	80128	4117	E-CARCINOMA,MAMMARY GLAND
7	.11	.0011	.00002		4.7	8.3	8.4	8.4	74310	2148	D-RENAL AMYLOIDOSIS
5	.13	.0030	.00010		5.6	10.	10.	10.	83173	5298	D-INTERSTITIAL NEPHRITIS
7	.10	.0022	.00004		4.8	8.2	8.3	8.3	79184	3784	D-PYOMETRA
6	.14	.0050	.00015		5.5	12.	12.	12.	82195	5144	D-HEMANGIOSARCOMA,LIVER
6	.15	.0060	.00020		5.8	13.	13.	13.	78206	3529	E-BRAIN EDEMA,UNDETERMINED CAUSE
6	.17	.014	.00060		6.3	15.	15.	15.	81334	4753	D-HEPATIC ATROPHY
6	.099	.0030	.00005		4.8	8.7	8.8	8.8	79312	3936	E-CARCINOMA,NASAL CAVITY
5	.12	.0018	.00003		4.7	9.8	9.9	9.9	81327	4861	D-CARCINOMA,STOMACH
2	.11	.0041	.00005		5.2	9.7	9.9	9.9	83090	5151	E-RENAL CORTICAL FIBROSIS
1	.12	.0025	.00005		4.8	9.5	9.7	9.7	80072	4241	E-SARCOMA,MAMMARY GLAND
0	.072	.00083	.00001		3.4	5.9	5.9	5.9	80120	4338	D-RENAL AMYLOIDOSIS
1	.10	.0020	.00003		4.4	8.1	8.2	8.2	79269	3933	E-TUMOR, LIVER
9	.079	.0013	.00001		3.3	6.4	6.5	6.5	83027	5342	E-PYELONEPHRITIS
9	.10	.0045	.00040		4.2	8.8	9.1	9.1	81266	4685	E-CARCINOMA,MAMMARY GLAND
9	.084	.0013	.00004		3.5	6.4	6.5	6.5	82217	4977	E-MEDIASTINAL TUMOR
9	.065	.0015	.00006		3.2	5.6	5.7	5.7	81282	4637	D-CNS DISTURBANCE
7	.081	.0030	.00008		3.5	6.9	7.1	7.1	80046	4011	D-CARCINOMA,MAMMARY;TUMOR, NASAL CAVITY

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A.6 $^{137}CsCl$, Longevity Study (continued)

DOG IDENTIFICATION			INJECTION EXPOSURE				I.B.B.					BETA RADIATION DOSE DOSE RATE (GY/DAY)				
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	30 DAYS	180 DAYS	365 DAYS	AT DEAT
285A	03-562	M	I	69028	393	10.5	50	920	9700	34	360	.17	.063	.0020	.00002	
287A	04-567	M	K	69052	410	10.2	51	900	9200	33	340	.17	.080	.0028	.00007	
249C	02-540	M	D	68215	422	8.8	52	900	7900	33	290	.17	.086	.0022	.00002	
266A	03-558	M	E	68330	435	9.1	53	890	8100	33	300	.16	.079	.0015	.00004	
248C	02-539	F	C	68214	427	8.3	54	880	7300	33	270	.16	.076	.0011	.00002	
241C	01-522	M	A	68164	418	9.7	C									
244D	01-523	F	B	68165	403	7.2	C									
251D	01-539	F	C	68214	408	6.8	C									
247B	01-540	M	D	68215	429	9.4	C									
267D	02-558	F	F	68330	435	7.4	C									
270B	C1-558	M	E	68330	423	8.4	C									
274E	01-560	F	H	68354	419	7.1	C									
277A	02-560	M	G	68354	392	9.4	C									
282A	01-562	M	I	69028	402	8.6	C									
283C	02-562	F	J	69028	395	8.8	C									
282D	02-567	F	L	69052	426	6.9	C									
286C	01-567	M	K	69052	417	8.4	C									

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS AI

BETA RADIATION DOSE TO WHOLE BODY

DOSE RATE (GY/DAY)				CUMULATIVE (GY)						
30 AYS	180 DAYS	365 DAYS	AT DEATH	30 DAYS	180 DAYS	365 DAYS	AT DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
063	.0020	.00002		3.1	5.4	5.5	5.5	82028	4748	E-CARCINOMA,BLADDER
080	.0028	.00007		3.6	6.7	6.9	6.9	75332	2471	E-NEUROFIBROSARCOMA,LIVER
086	.0022	.00002		3.4	7.0	7.1	7.1	81015	4549	E-CARCINOMA,BLADDER
079	.0015	.00004		3.3	6.3	6.4	6.4	81056	4475	E-HEMANGIOSARCOMA,SPLEEN
076	.0011	.00002		3.3	6.1	6.1	6.1	80318	4487	E-LIVER DEGEN.;CARC.,LIVER;CARC.,LUNG
								82313	5263	E-INTERSTITIAL NEPHRITIS
								70081	647	D-HEMOLYTIC ANEMIA;ENDOCARDITIS
								83054	5319	E-INTERSTITIAL NEPHRITIS
								84233	5862	E-PYELONEPHRITIS
								79225	3913	D-ENDOMETRITIS; PERITONITIS
								83364	5513	D-ADENOCARCINOMA,PROSTATE
								77154	3088	D-CARCINOMA,MAMMARY GLAND
								75239	2442	D-RENAL AMYLOIDOSIS
								84130	5580	E-THROMBOSIS,AORTA
								85199	6015	D-BRONCHIOLOALVEOLAR CARC.,LUNG
								78030	3265	E-RENAL FAILURE;UREMIA
								82011	4707	E-PYELONEPHRITIS

:ON EXPOSURE.

:LY. PROMINENT FINDINGS ARE INCLUDED.

2

A.7 ^{90}Y in Fused Aluminosilicate Particles, Longevity Study

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					BETA RADIATION DOSE T		
														RATE (GY/MIN)		CUMUL
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	AT DEATH	INFIN.
333A	02-661	M	A	69266	415	10.3	230.	2300	01	5200	53000	190.	2000	.15	.030	810
333T	01-661	F	B	69266	415	8.6	180.	1600	02	3600	31000	130.	1100	.10	.005	570
347S	02-684	F	D	69322	379	9.8	130.	1300	03	2800	27000	100.	1000	.080		440
340C	03-684	M	C	69322	419	10.6	130.	1400	04	2600	28000	96.	1000	.076		410
332V	01-662	F	B	69267	418	5.5	150.	850	05	2400	13000	89.	480	.060		370
339A	04-684	M	C	69322	422	9.8	89.	850	06	1900	19000	70.	700	.056		300
335S	03-661	F	B	69266	399	9.7	96.	930	07	1900	18000	70.	670	.055		290
334A	04-661	M	A	69266	406	11.4	85.	960	08	1700	19000	63.	700	.048		270
341T	03-685	F	D	69323	417	9.0	93.	810	09	1700	15000	63.	560	.048		270
340U	01-684	F	D	69322	419	9.8	170.	1700	10	1600	16000	59.	590	.048		250
341C	02-685	M	C	69323	417	10.1	67.	670	11	1500	15000	56.	560	.044		240
340B	05-685	M	C	69323	421	10.6	63.	670	12	1400	15000	52.	560	.042		230
334B	02-662	M	A	69267	407	10.6	70.	740	13	1400	15000	52.	560	.041		230
332T	04-662	F	B	69267	418	8.0	70.	560	14	1400	11000	52.	410	.041		220
347B	04-685	M	C	69323	380	8.5	56.	480	15	1300	11000	48.	410	.038		200
335A	03-662	M	A	69267	400	9.6	59.	560	16	1100	11000	41.	410	.032		180
343V	01-685	F	D	69323	395	7.1	96.	670	17	1100	7500	41.	280	.030		170
406U	04-820	F	H	70258	409	8.4	52.	440	18	1100	8800	41.	330	.030		170
339S	05-662	F	B	69267	367	7.7	67.	520	19	1000	7800	37.	290	.029		170
406A	03-820	M	G	70258	409	12.0	56.	670	20	980	12000	36.	440	.027		150
448U	02-874	F	L	71089	411	8.4	67.	560	21	900	7600	33.	280	.027		140
439A	03-863	M	I	71053	402	13.1	48.	630	22	850	11000	31.	410	.024		140
343C	03-686	M	C	69325	397	9.3	32.	300	23	760	7100	28.	260	.022		120
437T	01-863	F	J	71053	406	7.6	30.	230	24	740	5600	27.	210	.022		120
380B	01-746	M	E	70124	394	9.0	36.	320	25	730	6600	27.	240	.022		120
451B	04-874	M	K	71089	401	9.5	41.	370	26	730	6900	27.	260	.022		120
403T	02-820	F	H	70258	416	6.9	34.	230	27	710	4900	26.	180	.020		110
449U	01-874	F	L	71089	408	5.9	44.	260	28	710	4200	26.	160	.020		110
452B	03-874	M	K	71089	401	9.8	41.	410	29	700	6900	26.	260	.020		110
341S	02-686	F	D	69325	419	9.8	35.	340	30	690	6800	26.	250	.020		110
413A	01-821	M	G	70259	383	11.2	29.	320	31	680	7600	25.	280	.020		110
333B	06-662	M	A	69267	416	11.9	36.	440	32	680	8000	25.	300	.019		110
448B	04-863	M	I	71053	375	9.8	31.	310	33	670	6600	25.	240	.019		100
402C	01-820	M	G	70258	417	7.0	29.	200	34	660	4700	24.	170	.019		100
404U	03-821	F	H	70259	416	5.9	32.	190	35	640	3700	24.	140	.019		100
434T	02-863	F	J	71053	415	7.3	30.	220	36	640	4700	24.	170	.019		100
446C	03-864	M	I	71054	380	11.2	25.	280	37	600	6700	22.	250	.018		95
436U	01-864	F	J	71054	412	9.1	34.	310	38	590	5300	22.	200	.018		93
371S	03-746	F	F	70124	423	7.8	25.	190	39	590	4600	22.	170	.018		93
400T	04-821	F	H	70259	426	6.5	21.	130	40	500	3300	19.	120	.015		79
378B	04-746	M	E	70124	410	10.3	26.	260	41	490	5100	18.	190	.014		77
333S	02-663	F	B	69268	417	7.6	22.	160	42	460	3500	17.	130	.014		72
450B	03-875	M	K	71090	406	9.4	21.	200	43	450	4200	17.	160	.013		71
446S	04-864	F	J	71054	380	8.1	21.	170	44	420	3400	16.	130	.012		66
332C	01-663	M	A	69268	419	8.5	19.	160	45	410	3500	15.	130	.012		65
449S	04-875	F	L	71090	409	7.9	21.	160	46	400	3200	15.	120	.012		64
400U	01-817	F	H	70251	418	7.6	20.	150	47	400	3000	15.	110	.012		62
411C	02-821	M	G	70259	394	9.2	21.	190	48	380	3500	14.	130	.011		60
439C	02-864	M	I	71054	403	9.7	26.	250	49	380	3700	14.	140	.011		60

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BETA RADIATION DOSE TO LUNG

RATE (GY/MIN)		CUMULATIVE (GY)				
INITIAL	AT DEATH	INFIN.	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
.15	.030	810+	700	69273	7	D-PULMONARY INJURY
.10	.005	570+	550	69278	12	D-PULMONARY INJURY
.080		440	440	70004	47	D-PULMONARY INJURY
.076		410	410	69353	31	D-PULMONARY INJURY
.060		370	370	69342	75	D-PULMONARY INJURY
.056		300	300	70021	64	D-PULMONARY INJURY
.055		290	290	69336	70	D-PULMONARY INJURY
.048		270	270	69304	38	E-PULMONARY INJURY
.048		270	270	70033	75	D-PULMONARY INJURY
.048		250	250	70045	88	D-PULMONARY INJURY
.044		240	240	70043	85	D-PULMONARY INJURY
.042		230	230	70048	90	D-PULMONARY INJURY
.041		230	230	69290	23	D-PULMONARY INJURY
.041		220	220	69356	89	E-PULMONARY INJURY
.038		200	200	70033	75	D-PULMONARY INJURY
.032		180	180	69358	91	D-PULMONARY INJURY
.030		170	170	70050	92	D-PULMONARY INJURY
.030		170	170	70349	91	D-PULMONARY INJURY
.029		170	170	69349	82	D-PULMONARY INJURY
.027		150	150	71001	108	D-PULMONARY INJURY
.027		140	140	71230	141	D-PULMONARY INJURY
.024		140	140	71158	105	D-PULMONARY INJURY
.022		120	120	70077	117	D-PULMONARY INJURY
.022		120	120	71175	122	D-PULMONARY INJURY
.022		120	120	70323	199	D-PULMONARY INJURY
.022		120	120	71232	143	D-PULMONARY INJURY
.020		110	110	71023	130	D-PULMONARY INJURY
.020		110	110	73261	903	D-PULMONARY FIBROSIS;ADENOMA,LUNG
.020		110	110	71210	121	D-PULMONARY INJURY
.020		110	110	70123	163	E-PULMONARY INJURY
.020		110	110	71108	214	D-PULMONARY INJURY
.019		110	110	70028	126	D-PULMONARY INJURY
.019		100	100	77139	2278	E-FIBROSARCOMA,LUNG;OSTEOPATHY
.019		100	100	71356	463	D-PULMONARY INJURY
.019		100	100	71114	220	D-PULMONARY INJURY
.019		100	100	71176	123	D-PULMONARY INJURY
.018		95	95	71291	237	D-PULMONARY INJURY
.018		93	93	71259	205	D-PULMONARY INJURY
.018		93	93	70306	182	D-PULMONARY INJURY
.015		79	79	79172	3200	D-CONGESTIVE HEART FAILURE
.014		77	77	77194	2627	E-BRONC.ALV.CARC.;OSTEOSARC.,VERT.
.014		72	72	75327	2250	D-BRONCHIOLOALVEOLAR CARCINOMA
.013		71	71	80131	3328	D-CARCINOMA,LUNG
.012		66	66	77239	2377	E-CARCINOMA;SITE UNDETERMINED
.012		65	65	78013	3032	E-SQUAMOUS CELL CARCINOMA,LUNG
.012		64	64	84295	4953	D-CONGESTIVE HEART FAILURE
.012		62	62	83010	4507	E-ADENOCARCINOMA,MAMMARY
.011		60	60	80118	3511	D-HEART FAILURE
.011		60	60	80178	3411	E-HEART FAILURE

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(1)

A.7 ^{90}Y in Fused Aluminosilicate Particles, Longevity Study (continued)

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					BETA RADIATION DOSE TO LUNG RATE (GY/MIN)		CUMULATIVE (…	
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	AT DEATH	INFIN.	TO DE…
411D	04-817	M	G	70251	386	9.8	16.	150	50	380	3700	14.	140	.011		60	6…
452A	01-875	M	K	71090	402	9.6	20.	190	51	380	3600	14.	130	.011		60	6…
449T	02-875	F	L	71090	409	8.2	20.	160	52	380	3100	14.	110	.011		60	6…
374T	02-746	F	F	70124	414	8.0	17.	140	53	370	3000	14.	110	.011		58	5…
348C	04-686	M	C	69325	376	8.7	25.	210	54	360	3200	13.	120	.011		57	5…
343T	01-686	F	D	69325	397	8.5	16.	140	55	360	3100	13.	110	.011		57	5…
434S	01-867	F	J	71055	417	9.4	16.	150	56	340	3200	13.	120	.0096		53	5…
407S	02-817	F	H	70251	402	7.2	16.	120	57	320	2300	12.	85	.0093		51	5…
380D	01-747	M	E	70125	395	9.4	15.	140	58	300	2900	11.	110	.0090		48	4…
406B	03-817	M	G	70251	402	12.1	18.	210	59	300	3600	11.	130	.0088		48	4…
446D	04-867	M	I	71055	381	11.4	17.	190	60	300	3400	11.	130	.0088		48	4…
375U	02-747	F	F	70125	415	7.6	14.	110	61	290	2200	11.	81	.0088		48	4…
437S	03-867	F	J	71055	408	8.4	16.	130	62	280	2300	10.	85	.0080		44	44
441A	02-867	M	I	71055	399	9.0	13.	110	63	270	2400	10.	89	.0079		43	4…
399A	02-818	M	G	70252	422	9.0	10.	93	64	260	2300	9.6	85	.0075		41	41
377B	03-747	M	E	70125	412	9.0	13.	110	65	250	2300	9.3	85	.0072		39	3…
450C	01-876	M	K	71091	407	10.4	10.	100	66	250	2600	9.3	96	.0072		39	3…
339U	04-687	F	D	69328	428	7.2	12.	85	67	240	1700	8.9	63	.0069		38	3…
372S	04-747	F	F	70125	423	9.6	12.	110	68	230	2200	8.5	81	.0069		36	3…
339B	01-687	M	C	69328	428	9.1	8.5	78	69	230	2100	8.5	78	.0065		36	3…
332S	03-663	F	B	69268	419	8.6	10.	89	70	220	1900	8.1	70	.0065		36	3…
447U	04-876	F	L	71091	414	6.6	10.	67	71	220	1500	8.1	56	.0065		34	34
335B	04-663	M	A	69268	401	9.8	10.	100	72	190	1900	7.0	70	.0056		30	30
408U	01-818	F	H	70252	395	9.0	9.6	89	73	190	1700	7.0	63	.0056		30	30
438S	01-868	F	J	71056	405	9.7	16.	150	74	190	1800	7.0	67	.0055		30	30
447B	03-868	M	I	71056	379	7.3	11.	78	75	180	1300	6.7	48	.0052		28	28
377S	01-748	F	F	70126	413	9.9	7.0	70	76	150	1500	5.5	56	.0043		24	24
380C	03-748	M	E	70126	396	10.2	6.7	70	77	140	1500	5.2	56	.0043		23	23
339T	02-665	F	B	69269	369	6.4	7.0	44	78	130	830	4.8	31	.0038		20	20
407B	03-818	M	G	70252	403	10.6	7.0	74	79	130	1300	4.8	48	.0037		20	20
450E	03-876	M	K	71091	407	10.2	6.3	63	80	130	1300	4.8	48	.0037		20	20
448T	02-876	F	L	71091	413	8.3	5.2	44	81	120	960	4.4	36	.0033		19	19
343A	03-687	M	C	69328	400	9.3	4.4	41	82	110	1000	4.1	37	.0033		18	18
405U	04-818	F	H	70252	403	6.8	5.5	37	83	110	720	4.1	27	.0030		17	17
334C	01-665	M	A	69269	409	8.3	5.2	44	84	100	850	3.7	31	.0030		17	17
436V	04-868	F	J	71056	414	7.4	6.7	48	85	100	750	3.7	28	.0029		15	15
438B	02-868	M	I	71056	405	8.6	5.5	48	86	98	840	3.6	31	.0028		15	15
379B	02-748	M	E	70126	402	10.7	4.1	44	87	90	960	3.3	36	.0027		14	14
372T	04-748	F	F	70126	424	10.4	3.4	36	88	83	860	3.1	32	.0023		13	13
340T	02-687	F	D	69328	425	10.2	3.7	41	89	80	810	3.0	30	.0023		13	13
333E	01-660	M	A	69265	414	9.5			C								
334T	02-660	F	B	69265	405	8.5			C								
348S	02-683	F	D	69321	372	9.0			C								
349B	01-683	M	C	69321	372	12.2			C								
378A	01-745	M	E	70121	407	11.6			C								
383U	02-745	F	F	70121	375	6.0			C								
401A	02-812	M	G	70247	413	9.2			C								
407T	01-812	F	H	70247	398	8.0			C								
438U	02-862	F	J	71050	399	7.8			C								
441B	01-862	M	I	71050	394	8.6			C								
447W	02-873	F	L	71085	408	6.6			C								
448A	01-873	M	K	71085	407	10.0			C								

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE INCLUDE…

3ETA RADIATION DOSE TO LUNG

TE (GY/MIN)		CUMULATIVE (GY)		DEATH	DAYS TO	
IAL	AT DEATH	INFIN.	TO DEATH	DATE	DEATH	COMMENT
1		60	60	81247	4014	D-LYMPHOSARCOMA,LIVER
1		60	60	82146	4074	E-ORAL MELANOSARCOMA
1		60	60	82036	3964	E-MAMMARY CARCINOMA
1		58	58	81195	4089	D-PULMONARY FIBROSIS;CARCINOMA,LUNG
1		57	57	84213	5366	E-BRONCHIOLOALVEOLAR CARCINOMA,LUNG
1		57	57	80231	3923	D-HEMOLYTIC ANEMIA
96		53	53	82295	4258	D-CONGESTIVE HEART FAILURE
93		51	51	83062	4559	E-INTERSTITIAL PNEUMONIA
90		48	48	79189	3351	D-UREMIA
28		48	48	80197	3598	D-INTERSTITIAL PNEUMONIA
38		48	48	81124	3722	E-LYMPHOSARCOMA,LIVER
38		48	48	83341	4964	E-ADENOCARCINOMA,MAMMARY GLAND
20		44	44	84221	4914	E-ADENOCARCINOMA,NASAL
79		43	43	86013	5437	E-CARCINOMA,LUNG
75		41	41	81290	4056	D-RENAL TUMORS
72		39	39	85254	5608	E-HEMANGIOSARCOMA,MUSCLE
72		39	39	84164	4821	D-SQUAMOUS CELL CARCINOMA,TONSIL
59		38	38	80325	4014	E-ADENOCARCINOMA,MAMMARY GLAND
59		36	36	83084	4707	D-ADENOCARCINOMA,JEJUNUM
55		36	36	81263	4318	D-RENAL AMYLOIDOSIS
55		36	36	85089	5665	E-CARCINOMA,LUNG
55		34	34	82209	4136	D-EPILEPSY
56		30	30	80293	4042	D-MENINGIOMA
56		30	30	82105	4236	E-PITUITARY TUMOR
55		30	30	82134	4096	E-LYMPHOSARCOMA
52		28	28	82348	4310	D-HISTEOCYTIC LYMPHOSARCOMA,LIVER
.3		24	24	85019	5372	E-CARCINOMA,MAMMARY GLAND
.3		23	23	79058	3219	D-ENCEPHALITIS
8		20	20	81189	4303	E-THROMBOEMBOLISM
7		20	20	86086	5678	E-DEGENERATIVE DISC DISEASE
7		20	20	87006	5759	E-LYMPHOSARCOMA,SKIN
3		19	19	81230	3792	D-ENDOMETRITIS;CARCINOMA,LUNG
3		18	18	84349	5499	D-CONGESTIVE HEART FAILURE
0		17	17	83266	4762	D-ENTERITIS
.0		17	17	82018	4497	E-DISC PROTRUSION
9		15	15	84122	4814	E-CARCINOMA,MAMMARY GLAND
8		15	15	82288	4250	D-HISTEOCYTIC LYMPHOSARCOMA,SPLEEN
7		14	14	81042	3934	D-PROSTATITIS;CARCINOMA,SALIVARY
.3		13	13	81285	4177	D-HEPATIC DEGENERATION
.3		13	13	82208	4628	D-PANCREATIC ISLET CELL CARCINOMA
				82084	4567	E-RENAL ATROPHY
				81005	4123	E-NECROTIZING ARTERITIS
				82174	4601	E-CARCINOMA,LUNG
				85265	5788	D-CONGESTIVE HEART FAILURE
				83223	4850	E-CARCINOMA,LUNG
				85154	5512	E-NEPHROSCLEROSIS
				83179	4680	D-CARCINOMA,LUNG
				85114	5346	E-CARCINOMA,LUNG
				86041	5470	D-THROMBOSIS,LUNG
				83067	4400	E-OSTEOSARCOMA,SACRUM;CARCINOMA,PROSTATE
				81090	3658	D-ACCIDENTAL DEATH
				84080	4743	D-NEPHRITIS,CHRONIC

URE.

MINENT FINDINGS ARE INCLUDED.

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A.8 ^{91}Y in Fused Aluminosilicate Particles, Longevity Study

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					DOSE RATE (		
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS	120 DAYS
386T	04-759	F	D	70154	400	13.5	37.	520.	01	360	4900	13.	180.	9.9	4.4	
375A	01-722	M	A	70079	369	10.4	32.	330.	02	320	3300	12.	120.	8.8	3.6	1.5
384A	02-758	M	C	70153	404	12.0	28.	340.	03	300	3600	11.	130.	8.3	3.9	1.8
383S	01-760	F	B	70155	409	11.0	31.	340.	04	300	3300	11.	120.	8.3	3.6	1.5
384S	02-759	F	B	70154	405	10.9	26.	280.	05	300	3300	11.	120.	8.2	3.6	1.6
372A	03-724	M	A	70082	380	11.2	25.	280.	06	270	3100	10.	110.	7.5	3.2	1.3
384B	03-758	M	C	70153	404	10.2	24.	240.	07	260	2700	9.6	100.	7.2	3.2	1.4
392U	01-761	F	D	70156	368	9.4	17.	160.	08	260	2400	9.6	89.	7.1	3.2	1.4
385A	03-759	M	C	70154	401	11.0	13.	140.	09	230	2600	8.5	96.	6.4	2.8	1.2
393S	01-758	F	B	70153	362	10.8	14.	160.	10	210	2300	7.8	85.	5.7	2.5	1.1
374A	03-722	M	A	70079	369	10.8	11.	110.	11	200	2100	7.4	78.	5.3	2.4	1.1
387V	02-760	F	D	70155	399	7.1	15.	100.	12	190	1300	7.0	48.	5.2	2.3	1.0
489C	01-951	M	K	71257	382	7.6	13.	100.	13	190	1500	7.0	56.	5.2	2.2	0.96
484E	01-953	M	K	71259	398	9.1	11.	100.	14	180	1700	6.7	63.	5.1	2.1	0.90
423C	03-835	M	E	70342	391	8.9	8.5	74.	15	170	1500	6.3	56.	4.6	2.0	0.86
426S	04-834	F	F	70341	386	7.9	12.	96.	16	170	1300	6.3	48.	4.3	1.9	0.81
491A	04-952	M	I	71258	368	9.8	14.	140.	17	170	1700	6.3	63.	4.7	2.0	0.84
483T	04-951	F	L	71257	396	6.4	10.	63.	18	170	1100	6.3	41.	4.5	2.0	0.88
484S	03-952	F	J	71258	397	7.2	14.	96.	19	170	1200	6.3	44.	4.5	1.9	0.82
374B	01-724	M	A	70082	372	9.4	12.	110.	20	160	1500	5.9	56.	4.3	1.9	0.82
385D	01-759	M	C	70154	401	9.4	13.	120.	21	160	1500	5.9	56.	4.3	1.9	0.84
385S	04-758	F	B	70153	400	8.8	17.	150.	22	150	1300	5.5	48.	4.0	1.8	0.78
420C	01-834	M	G	70341	401	10.9	13.	140.	23	150	1700	5.5	63.	4.2	1.9	0.84
419V	04-835	F	H	70342	415	7.1	6.3	44.	24	150	1100	5.5	41.	4.2	1.8	0.79
491B	01-952	M	I	71258	368	9.0	7.4	67.	25	150	1300	5.5	48.	4.1	1.7	0.72
390V	02-761	F	D	70156	376	7.6	17.	130.	26	140	1100	5.2	41.	3.8	1.7	0.77
492A	03-956	M	I	71264	374	11.3	11.	120.	27	140	1500	5.2	56.	3.7	1.5	0.60
422C	02-834	M	E	70341	397	10.8	7.4	81.	28	130	1400	4.8	52.	3.7	1.6	0.69
485U	02-951	F	J	71257	394	6.2	8.1	52.	29	130	830	4.8	31.	3.6	1.5	0.65
489B	01-954	M	K	71260	386	10.0	8.9	89.	30	130	1300	4.8	48.	3.6	1.5	0.64
420U	01-836	F	F	70343	403	7.3	9.3	67.	31	120	880	4.4	33.	3.3	1.5	0.66
420B	01-837	M	G	70344	404	10.4	7.8	81.	32	120	1300	4.4	48.	3.3	1.5	0.64
422S	02-835	F	H	70342	398	11.3	10.	120.	33	120	1400	4.4	52.	3.3	1.4	0.58
490T	02-952	F	J	71258	369	7.9	5.2	41.	34	120	920	4.4	34.	3.2	1.4	0.62
430A	01-835	M	E	70342	372	11.6	21.	240.	35	110	1200	4.1	44.	3.0	1.3	0.60
425T	03-834	F	F	70341	387	8.2	13.	110.	36	110	940	4.1	35.	3.3	1.4	0.61
484V	04-953	F	L	71259	398	6.0	6.7	41.	37	110	680	4.1	25.	3.0	1.3	0.56
376B	02-724	M	A	70082	370	8.4	10.	85.	38	110	900	4.1	33.	3.0	1.3	0.56
422B	03-838	M	E	70348	404	11.4	5.9	67.	39	110	1200	4.1	44.	2.9	1.3	0.56
428A	02-841	M	G	70351	393	9.4	7.4	70.	40	110	1100	4.1	41.	3.1	1.3	0.57
484B	03-951	M	I	71257	396	8.6	6.3	56.	41	110	930	4.1	34.	2.9	1.2	0.52
489S	02-956	F	J	71264	390	8.1	6.7	52.	42	110	890	4.1	33.	3.0	1.3	0.52
387S	01-767	F	D	70162	406	7.7	12.	96.	43	100	800	3.7	30.	2.8	1.2	0.51
419T	02-838	F	F	70348	421	7.8	9.3	70.	44	100	800	3.7	30.	2.8	1.2	0.54
490S	03-954	F	L	71260	372	8.1	7.0	56.	45	100	850	3.7	31.	2.9	1.2	0.51
390T	04-766	F	B	70161	381	8.6	7.4	63.	46	97	830	3.6	31.	2.6	1.2	0.51
483D	02-953	M	I	71259	398	7.7	5.2	41.	47	94	720	3.5	27.	2.5	1.1	0.48
490A	02-954	M	K	71260	372	9.2	5.5	52.	48	92	840	3.4	31.	2.5	1.1	0.45
492S	04-956	F	J	71264	374	8.0	10.	85.	49	90	720	3.3	27.	2.5	0.94	0.36

BETA RADIATION DOSE TO LUNG

	DOSE RATE (GY/DAY)				CUMULATIVE (GY)							
INITIAL	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
9.9	4.4			2.1	410			730+	570	70267	113	D-PULMONARY INJURY
8.8	3.6	1.5		1.1	350	490		590+	510	70219	140	D-PULMONARY INJURY
8.3	3.9	1.8		0.69	350	510		650+	600	70347	194	D-PULMONARY INJURY
8.3	3.6	1.5		0.85	340	480		590+	530	70317	162	D-PULMONARY INJURY
8.2	3.6	1.6		0.51	340	480		600+	560	70356	202	D-PULMONARY INJURY
7.5	3.2	1.3		0.53	30	430		520+	490	70267	185	D-PULMONARY INJURY
7.2	3.2	1.4		0.30	300	430		530+	510	71024	236	D-PULMONARY INJURY
7.1	3.2	1.4		0.91	290	420		530+	460	70309	153	D-PULMONARY INJURY
6.4	2.8	1.2		0.59	260	380		460+	420	70327	173	D-PULMONARY INJURY
5.7	2.5	1.1		0.48	230	330		410+	370	70330	177	D-PULMONARY INJURY
5.3	2.4	1.1		0.75	220	320		400+	340	70226	147	D-PULMONARY INJURY
5.2	2.3	1.0		0.96	210	300		380+	310	70278	123	D-PULMONARY INJURY
5.2	2.2	0.96		0.078	210	300		370	370	72190	298	D-PULMONARY INJURY
5.1	2.1	0.90		0.24	200	290		350+	340	72107	213	D-PULMONARY INJURY
4.6	2.0	0.86		0.49	190	270		330+	290	71137	160	D-PULMONARY INJURY
4.3	1.9	0.81		0.28	180	250		310+	290	71172	196	D-PULMONARY INJURY
4.7	2.0	0.84		0.29	190	270		330+	310	72089	196	D-PULMONARY INJURY
4.5	2.0	0.88		0.041	180	270		330	330	72238	346	D-PULMONARY INJURY
4.5	1.9	0.82		0.39	180	260		320+	290	72065	172	D-PULMONARY INJURY
4.3	1.9	0.82		0.64	180	250		310+	260	70219	137	D-PULMONARY INJURY
4.3	1.9	0.84		0.36	180	260		320+	290	70335	181	D-PULMONARY INJURY
4.0	1.8	0.78		0.097	160	240		290	290	71062	274	D-PULMONARY INJURY
4.2	1.9	0.84		0.55	170	250		310+	270	71128	152	D-PULMONARY INJURY
4.2	1.8	0.79		0.50	170	240		300+	270	71130	153	D-PULMONARY INJURY
4.1	1.7	0.72		0.30	160	230		280+	260	72074	181	E-PULMONARY INJURY
3.8	1.7	0.77		0.13	160	230		290+	280	71043	252	E-PULMONARY INJURY
3.7	1.5	0.60		0.14	140	200		240+	230	72115	216	D-PULMONARY INJURY
3.7	1.6	0.69		0.30	150	210		260+	240	71155	179	D-PULMONARY INJURY
3.6	1.5	0.65	.019		150	210	250	250	250	74276	1115	D-BRONCHIOLOALVEOLAR CARCINOMA
3.6	1.5	0.64	.019		140	200	250	250	250	75234	1435	E-HEMANGIOSARCOMA,TBLN; B.A.CARCINOMA
3.3	1.5	0.66		0.42	140	200		250+	220	71137	159	E-PULMONARY INJURY
3.3	1.5	0.64		0.30	140	200		240+	220	71153	174	D-PULMONARY INJURY
3.3	1.4	0.58		0.27	130	190		230+	210	71150	173	D-PULMONARY INJURY
3.2	1.4	0.62	.022		130	190	230	230	230	76293	1861	D-BRONCHIOLOALVEOLAR CARCINOMA
3.0	1.3	0.60		0.059	120	180		220	220	71272	295	E-PULMONARY INJURY
3.3	1.4	0.61	.020		130	190	230	230	230	74268	1388	D-ADENOCARCINOMA,BROCHOGENIC
3.0	1.3	0.56	.015		120	180	210	210	210	75178	1380	E-COMBINED SQUAM.CELL-B.A.CARC.
3.0	1.3	0.56	.018	0.00004	120	170	210	210	210	72162	810	D-PULMONARY INJURY
2.9	1.3	0.56	.020		120	170	210	210	210	732[illegible]3	1011	D-PULMONARY INJURY
3.1	1.3	0.57	.018	0.00016	130	180	220	220	220	72325	704	D-PULMONARY INJURY
2.9	1.2	0.52	.015		120	170	200	200	200	75138	1342	D-BRONCHIOLOALVEOLAR CARCINOMA
3.0	1.3	0.52	.015		120	170	200	210	210	76321	1883	E-BRONCHIOLOALVEOLAR CARCINOMA
2.8	1.2	0.51	.016		110	160	200	200	200	77119	2514	D-BRONCHIOLOALVEOLAR CARCINOMA
2.8	1.2	0.54		0.35	110	170		200+	180	71135	152	D-PULMONARY INJURY
2.9	1.2	0.51		0.15	110	160		200+	190	72101	206	D-PULMONARY VASCULAR INJURY
2.6	1.2	0.51	.018		110	160	190	190	190	76307	2337	E-BRONCHIOLOALVEOLAR CARCINOMA
2.5	1.1	0.48	.016		100	150	180	180	180	79319	2982	E-CARCINOMA,LUNG
2.5	1.1	0.45		0.43	100	140		180+	150	72019	124	D-PULMONARY VASCULAR INJURY
2.5	0.[illegible]4	0.36	.0070		95	130	150	150	150	81035	3424	D-CARCINOMA,LUNG

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A.8 ^{91}Y in Fused Aluminosilicate Particles, Longevity Study (continued)

(1)

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					BET DOSE RATE (GY/DA			
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS	120 DAYS	36 DA
428S	03-837	F	H	70344	386	7.1	7.8	56.	50	89	640	3.3	24.	2.5	1.1	0.51	.02
484D	01-956	M	I	71264	401	7.7	6.3	48.	51	88	670	3.3	25.	2.4	1.0	0.44	.01
488U	03-953	F	L	71259	389	8.5	4.4	41.	52	87	740	3.2	27.	2.4	1.0	0.45	.01
420A	04-841	M	E	70351	411	12.4	7.8	96.	53	82	1000	3.0	37.	2.2	1.1	0.51	.02
383C	01-766	M	C	70161	415	10.1	5.9	59.	54	80	820	3.0	30.	2.2	0.95	0.41	.01
432A	04-838	M	E	70348	367	9.7	4.8	44.	55	80	780	3.0	29.	2.2	0.99	0.44	.01
426A	01-838	M	G	70348	393	11.5	5.9	70.	56	79	910	2.9	34.	2.2	0.96	0.42	.01
485W	04-954	F	J	71260	398	6.6	4.8	32.	57	76	500	2.8	19.	2.1	0.98	0.46	.02
422T	03-841	F	F	70351	407	9.9	8.5	85.	58	75	740	2.8	27.	2.0	0.93	0.42	.01
425S	04-837	F	H	70344	390	10.5	10.	100.	59	73	760	2.7	28.	2.0	0.88	0.39	.01
491S	02-958	F	J	71265	376	8.1	4.1	33.	60	69	560	2.6	21.	1.9	0.75	0.30	.00
426T	02-837	F	F	70344	389	7.4	7.4	56.	61	67	490	2.5	18.	1.8	0.79	0.34	.01
487B	01-958	M	K	71265	396	7.2	5.2	37.	62	59	430	2.2	16.	1.6	0.72	0.32	.01
391T	02-766	F	D	70161	375	8.4	7.0	59.	63	59	500	2.2	19.	1.6	0.70	0.31	.01
382B	03-766	M	C	70161	417	6.8	4.4	31.	64	57	390	2.1	14.	1.6	0.69	0.30	.01
431A	01-839	M	E	70349	376	10.1	3.7	37.	65	49	500	1.8	19.	1.3	0.59	0.26	.00
492C	03-958	M	I	71265	375	7.2	3.4	24.	66	47	340	1.7	13.	1.3	0.54	0.23	
421T	02-836	F	F	70343	402	9.6	4.4	41.	67	45	430	1.7	16.	1.2	0.54	0.24	.00
489T	04-958	F	L	71265	391	7.7	3.6	28.	68	44	340	1.6	13.	1.2	0.50	0.21	.00
396X	03-767	F	B	70162	363	7.9	7.4	59.	69	44	340	1.6	13.	1.2	0.57	0.27	.01
430C	04-836	M	G	70343	373	7.9	3.3	26.	70	42	340	1.6	13.	1.1	0.48	0.20	.00
428T	02-840	F	H	70350	392	5.7	4.1	23.	71	41	230	1.5	8.5	1.1	0.49	0.22	.00
488B	04-959	M	I	71266	396	8.1	2.1	17.	72	39	310	1.4	11.	1.0	0.47	0.21	.00
372B	02-722	M	A	70079	377	11.6	10.	110.	73	35	400	1.3	15.	0.93	0.38	0.15	.00
387U	02-767	F	B	70162	406	7.8	3.4	27.	74	34	260	1.3	9.6	0.91	0.39	0.17	.00
396S	04-767	F	D	70162	363	8.8	2.9	26.	75	33	300	1.2	11.	0.93	0.42	0.19	.00
489D	02-959	M	K	71266	392	9.6	2.4	23.	76	33	320	1.2	12.	0.91	0.37	0.15	.00
424S	03-839	F	H	70349	398	9.3	1.4	13.	77	31	290	1.1	11.	0.85	0.37	0.16	.00
488S	01-960	F	J	71267	397	7.3	2.8	21.	78	31	230	1.1	8.5	0.85	0.37	0.16	.00
386A	03-763	M	C	70159	405	11.0	1.4	16.	79	30	330	1.1	12.	0.83	0.37	0.17	.00
376A	03-725	M	A	70084	372	8.4	1.5	13.	80	29	240	1.1	8.9	0.80	0.34	0.15	.00
420D	03-836	M	E	70343	403	9.3	4.1	37.	81	27	250	1.0	9.3	0.72	0.32	0.15	.00
429S	04-839	F	F	70349	382	10.2	3.2	33.	82	27	270	1.0	10.	0.72	0.32	0.14	.00
484T	03-960	F	L	71267	406	6.3	2.5	16.	83	27	180	1.0	6.7	0.73	0.30	0.12	.00
383V	04-763	F	D	70159	413	7.3	1.9	14.	84	23	170	0.85	6.3	0.64	0.27	0.11	.00
422A	02-839	M	G	70349	405	11.6	1.4	16.	85	19	230	0.70	8.5	0.53	0.23	0.096	.00
425A	01-840	M	G	70350	396	9.1	2.1	19.	86	19	180	0.70	6.7	0.52	0.23	0.10	.00
487S	04-960	F	J	71267	398	6.6	1.7	11.	87	19	130	0.70	4.8	0.52	0.23	0.099	.00
420S	04-840	F	H	70350	410	7.6	1.6	12.	88	18	140	0.67	5.2	0.50	0.23	0.11	.00
382C	02-763	M	C	70159	415	7.4	1.0	7.4	89	18	130	0.67	4.8	0.49	0.21	0.091	.00
487A	03-959	M	I	71266	397	8.1	1.1	8.9	90	16	130	0.59	4.8	0.42	0.19	0.083	.00
492B	02-960	M	K	71267	377	8.9	1.1	10.	91	16	140	0.59	5.2	0.43	0.18	0.078	.00
485T	01-959	F	L	71266	404	7.4	1.0	7.4	92	16	120	0.59	4.4	0.41	0.19	0.086	.00
373A	02-725	M	A	70084	378	9.0	1.4	12.	93	15	140	0.55	5.2	0.42	0.18	0.074	.00
383W	01-763	F	B	70159	413	7.8	1.6	13.	94	14	110	0.52	4.1	0.39	0.16	0.066	.00
423U	03-840	F	F	70350	399	8.3	1.3	8.1	95	13	110	0.48	4.1	0.35	0.15	0.066	.00
432B	01-841	M	E	70351	370	8.1	0.93	7.8	96	11	92	0.41	3.4	0.31	0.14	0.065	.00
370A	01-725	M	A	70084	393	9.6			C								
381B	03-755	M	C	70147	414	11.2			C								
385T	01-755	F	B	70147	394	8.1			C								
389W	02-755	F	D	70147	381	8.4			C								
420T	01-833	F	H	70338	398	8.7			C								
424A	02-833	M	E	70338	387	9.8			C								
428U	04-833	F	F	70338	380	6.3			C								
431B	03-833	M	G	70338	365	9.2			C								
483A	02-950	M	K	71256	395	9.1			C								
485S	03-950	F	J	71256	394	8.3			C								
488C	04-950	M	I	71256	386	8.2			C								
488T	01-950	F	L	71256	386	8.6			C								

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE IN

2

BETA RADIATION DOSE TO LUNG

DOSE RATE (GY/DAY)					CUMULATIVE (GY)							
INITIAL	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
2.5	1.1	0.51	.020		100	150	190	190	190	77163	2376	D-SQUAMOUS CELL CARCINOMA,LUNG
2.4	1.0	0.44	.014		96	140	170	170	170	80207	3230	D-CARCINOMA,LUNG
2.4	1.0	0.45	.013		97	140	170	170	170	77356	2289	D-SQUAMOUS CELL CARCINOMA, LUNG
2.2	1.1	0.51	.024	0.011	95	140	180	180	180	72047	426	D-PULMONARY INJURY
2.2	0.95	0.41	.013		90	130	160	160	160	77353	2749	E-SQUAMOUS CELL CARC. AND OSTEOSARC.,LUNG
2.2	0.99	0.44	.017		90	130	160	160	160	80198	3502	E-CARCINOMA,LUNG
2.2	0.96	0.42	.015		89	130	160	160	160	75135	1613	D-COMBINED SQUAMOUS CELL-B-A-CARCINOMA
2.1	0.98	0.46	.021		88	130	160	170	170	79228	2890	D-PULMONARY INJURY
2.0	0.93	0.42	.017		85	120	150	160	160	78212	2783	D-B-A-CARCINOMA AND OSTEOSARCOMA,LUNG
2.0	0.88	0.39	.014		81	120	140	150	150	78263	2841	E-SQUAMOUS CELL-B-A-CARCINOMA,LUNG
1.9	0.75	0.30	.0075		74	100	120	120	120	80358	3380	E-CARCINOMA,LUNG
1.8	0.79	0.34	.012		74	110	130	130	130	80340	3648	E-CARCINOMA,MAMMARY;CARCINOMA,LUNG
1.6	0.72	0.32	.012		67	97	120	120	120	84206	4689	E-BRONCHIOLOALVEOLAR CARCINOMA,LUNG
1.6	0.70	0.31	.010		65	94	120	120	120	81169	4026	E-CARCINOMA,ADRENAL CORTEX
1.6	0.69	0.30	.011		64	92	110	110	110	80115	3606	D-CARCINOMA,LUNG
1.3	0.59	0.26	.0089		55	79	97	97	97	76005	1847	E-HEMANGIOSARCOMA,SPLEEN
1.3	0.54	0.23		0.093	52	74		90+	83	72083	183	D-PULMONARY VASCULAR INJURY
1.2	0.54	0.24	.0091		50	72	90	91	91	84019	4789	E-FIBROMAS,VAGINA
1.2	0.50	0.21	.0060		47	67	81	82	82	86055	5269	E-VERTEBRAL FRACTURE
1.2	0.57	0.27	.012		51	75	95	96	96	79021	3146	E-HEMANGIOSARCOMA,HEART
1.1	0.48	0.20	.0058		46	65	78	79	79	82337	4377	D-CARCINOMA,COLON
1.1	0.49	0.22	.0076		45	65	31	81	81	84284	5047	E-ADENOCARCINOMA,MAMMARY GLAND
1.0	0.47	0.21	.0078		43	62	77	78	78	86359	5572	D-CARCINOMA,LUNG
0.93	0.38	0.15	.0037		37	52	61	62	62	80270	3843	D-GRANULOMATOUS INFECTION
0.91	0.39	0.17	.0059		37	53	64	64	64	81182	4038	E-CARCINOMA,MAMMARY GLAND
0.93	0.42	0.19	.0075		38	56	70	70	70	83165	4751	D-CARCINOMA,LUNG
0.91	0.37	0.15	.0041		36	51	61	61	61	84344	4826	D-CONGESTIVE FAILURE,HEART
0.85	0.37	0.16	.0058		35	50	62	62	62	82307	4341	E-CARCINOMA,LUNG
0.85	0.37	0.16	.0050		34	49	60	60	60	86294	5506	D-SEPTICEMIA
0.83	0.37	0.17	.0063		34	49	61	62	62	83124	4713	E-CARCINOMA,LUNG
0.80	0.34	0.15	.0055		32	46	56	56	56	79187	3390	E-TUMOR, NASAL CAVITY
0.72	0.32	0.15	.0055		30	43	54	54	54	86220	5721	E-HEART FAILURE
0.72	0.32	0.14	.0048		30	42	52	53	53	84047	4811	E-BRONCHIOLOALVEOLAR CARCINOMA,LUNG
0.73	0.30	0.12	.0030		29	40	48	48	48	83105	4221	D-CARCINOMA,LUNG
0.64	0.27	0.11	.0036		26	36	44	44	44	83221	4810	E-ADENOCARCINOMA,MAMMARY
0.53	0.23	0.096	.0029		21	31	37	37	37	86129	5624	E-CARCINOMA,LUNG
0.52	0.23	0.10	.0039		21	31	39	39	39	79125	3062	E-TUMOR, PITUITARY
0.52	0.23	0.099	.0042		21	30	38	38	38	83270	4376	E-CARCINOMA,LUNG
0.50	0.23	0.11	.0045		21	31	39	39	39	82177	4210	D-CARCINOMA,BLADDER
0.49	0.21	0.091	.0037		20	28	35	35	35	84182	5136	E-ADENOCARCINOMA,LUNG
0.42	0.19	0.083	.0030		17	25	31	31	31	83115	4232	E-CARCINOMA,LUNG
0.43	0.18	0.078	.0023		17	25	30	30	30	84117	4598	E-ADENOCARCINOMA,PERIANAL GLAND
0.41	0.19	0.086	.0035		17	25	31	31	31	85204	5052	D-ADENOCARCINOMA,MAMMARY GLAND
0.42	0.18	0.074	.0027		17	24	29	29	29	84043	5072	D-HEART FAILURE
0.39	0.16	0.066	.0028		16	22	26	26	26	84103	5057	E-PYOMETRA
0.35	0.15	0.066	.0022		14	20	25	25	25	84138	4901	E-NEPHRITIS,CHRONIC
0.31	0.14	0.065	.0026		13	19	24	24	24	83040	4437	E-CHOLANGIO HEPATITIS
										82091	4390	E-ACCIDENTAL DEATH
										86245	5942	E-ADENOMA,PITUITARY
										83178	4779	E-ADENOCARCINOMA,MAMMARY
										82171	4407	D-PYOMETRA
										85165	5386	E-INTERSTITIAL NEPHRITIS
										85079	5220	E-PROLAPSED DISC
										85017	5158	E-MALIGNANT MELANOMA,MOUTH
										79080	3029	D-UNDETERMINED
										85312	5170	E-NEPHROSCLEROSIS
										82001	3763	D-LYMPHOADENOPATHY
										86144	5367	D-RENAL CALCULI
										80332	3363	D-CARCINOMA,BLADDER

EXPOSURE.

PROMINENT FINDINGS ARE INCLUDED.

A.9 ^{144}Ce in Fused Aluminosilicate Particles, Longevity Study (Series I)

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					BETA DOSE RATE (GY/DAY			
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS	120 DAYS	365 DAY
228B	02-490	M	C	68029	372	8.4	20.	170.	01	210	1700	7.8	63.	13.	8.8	7.2	
210B	01-474	M	A	67348	419	7.9	16.	130.	02	190	1500	7.0	56.	11.	8.6	6.7	
209B	02-474	M	A	67348	421	9.1	11.	100.	03	190	1700	7.0	63.	10.	7.7	6.1	
208B	01-478	F	B	67355	432	11.0	17.	190.	04	180	2000	6.7	74.	10.	8.4	6.7	
211G	02-478	F	B	67355	424	7.5	10.	74.	05	120	890	4.4	33.	6.9	5.3	4.2	
226C	01-490	M	C	68029	374	7.8	11.	89.	06	96	740	3.6	27.	5.5	4.2	3.2	
217A	01-491	M	C	68030	407	8.8	4.8	41.	07	68	600	2.5	22.	3.8	2.9	2.2	
211A	03-473	M	A	67347	416	8.1	3.7	30.	08	66	540	2.4	20.	3.8	2.9	2.3	
211E	03-477	F	B	67354	423	8.6	4.4	41.	09	51	440	1.9	16.	2.9	2.2	1.7	.6
228A	02-491	M	C	68030	373	9.9	2.5	25.	10	34	330	1.3	12.	1.9	1.4	1.1	.4
211D	02-473	M	A	67347	416	7.1	2.0	14.	11	27	190	1.0	7.0	1.5	1.0	0.74	.2
211F	02-477	F	B	67354	423	8.7	1.4	12.	12	19	170	0.70	6.3	1.1	0.79	0.60	.2
223A	03-491	M	C	68030	382	9.8	1.3	12.	13	15	150	0.55	5.5	0.89	0.60	0.44	.1
208D	01-477	F	B	67354	431	5.9	0.96	5.5	14	15	91	0.55	3.4	0.89	0.68	0.53	.2
209C	01-473	M	A	67347	420	9.0	1.0	8.9	15	11	100	0.41	3.7	0.64	0.49	0.38	.1
208A	01-476	M	A	67353	430	8.9			C								
209D	02-476	F	B	67353	426	7.9			C								
220C	01-492	M	C	68032	391	10.2			C								

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE I

BETA RADIATION DOSE TO LUNG

	DOSE RATE (GY/DAY)					CUMULATIVE DOSE (GY)							
	INITIAL	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
	13.	8.8	7.2		7.0	640	1100		6700+	1300	68172	143	D-PULMONARY INJURY
	11.	8.6	6.7		5.3	580	1000		2700+	1400	68156	173	D-PULMONARY INJURY
	10.	7.7	6.[illegible]		4.7	530	940		2400+	1300	68164	181	D-PULMONARY INJURY
	10.	8.4	6.7		5.5	560	1000		2900+	1400	68172	182	D-PULMONARY INJURY
	6.9	5.3	4.2		3.4	370	650		1700+	840	68161	171	D-PULMONARY INJURY
	5.5	4.2	3.2		2.4	290	510		1200+	700	68218	189	E-PULMONARY INJURY
	3.8	2.9	2.2		1.7	200	360		830+	480	68216	186	D-PULMONARY INJURY
	3.8	2.9	2.3		1.2	200	360		880+	580	68239	257	D-PULMONARY INJURY
	2.9	2.2	1.7	.66	0.57	150	270	530	720+	560	69033	410	D-PULMONARY INJURY
	1.9	1.4	1.1	.42	0.015	98	170	340	460	460	71252	1318	E-HEMANGIOSARCOMA,LUNG
0	1.5	1.0	0.74	.24	0.012	76	130	230	300+	290	71071	1185	D-HEMANGIOSARCOMA,LUNG
3	1.1	0.79	0.60	.23		56	97	190	250	250	76317	3250	E-OSTEOSARCOMA,LUNG
5	0.89	0.60	0.44	.16		44	75	140	190	190	74309	2471	E-HEMANGIOSARCOMA,BONE
4	0.89	0.68	0.53	.20		47	83	170	220	220	74193	2396	D-HEMANGIOSARCOMA,TBLN.
7	0.64	0.49	0.38	.15		34	60	120	160	160	79143	4179	E-LYMPHOMA,VISCERAL
											82328	5454	D-RENAL ATROPHY
											80183	4578	D-RENAL AMYLOIDOSIS
											81042	4759	E-SQUAMOUS CELL CARCINOMA,TONSIL

N EXPOSURE.

Y. PROMINENT FINDINGS ARE INCLUDED.

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A.10 ^{144}Ce in Fused Aluminosilicate Particles, Longevity Study (Series II)

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					DOSE RATE (G		
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS	D
315V	02-595	F	D	69149	398	7.2	6.3	44.	01	66.	470.	2.4	17.	3.7	2.7	
298B	02-586	M	A	69121	399	9.1	4.8	44.	02	65.	590.	2.4	22.	3.7	2.9	
327A	01-642	M	E	69213	387	9.4	4.4	41.	03	56.	520.	2.1	19.	3.2	2.4	
479U	04-947	F	L	71225	379	6.8	6.7	44.	04	54.	360.	2.0	13.	3.2	1.9	.57
330S	02-642	F	F	69213	374	8.3	4.1	34.	05	53.	440.	2.0	16.	3.0	2.3	
297S	03-586	F	B	69121	402	10.4	6.3	67.	06	46.	470.	1.7	17.	2.7	2.0	.60
470A	03-947	M	K	71225	397	11.0	2.5	27.	07	44.	480.	1.6	18.	2.7	2.0	
465S	03-918	F	J	71176	382	7.9	3.7	30.	08	41.	330.	1.5	12.	2.4	1.8	
465A	04-918	M	I	71176	382	11.4	2.3	26.	09	41.	460.	1.5	17.	2.3	1.8	
330U	03-641	F	F	69212	373	6.0	3.1	19.	10	37.	220.	1.4	8.1	2.2	1.5	.42
315A	01-595	M	C	69149	398	10.9	4.8	15.	11	35.	380.	1.3	14.	2.0	1.3	.43
330B	04-641	M	E	69212	373	6.3	2.7	17.	12	34.	220.	1.3	8.1	2.0	1.4	.38
303A	01-586	M	A	69121	422	9.5	2.8	27.	13	33.	320.	1.2	12.	1.9	1.4	
454A	03-883	M	G	71106	402	8.8	2.5	22.	14	32.	280.	1.2	10.	1.9	1.4	.31
453S	04-883	F	H	71106	408	8.0	1.4	11.	15	29.	230.	1.1	8.5	1.7	1.3	.41
464B	01-918	M	I	71176	385	9.4	1.7	16.	16	27.	250.	1.0	9.3	1.6	1.1	.29
310T	02-594	F	D	69148	421	8.9	4.8	41.	17	26.	230.	0.96	8.5	1.5	1.1	.33
460S	02-918	F	J	71176	419	7.9	3.0	23.	18	24.	190.	0.89	7.0	1.5	0.97	.27
480S	02-947	F	L	71225	373	8.3	1.9	16.	19	24.	200.	0.89	7.4	1.5	1.0	.29
312B	03-594	M	C	69148	399	9.0	1.8	16.	20	24.	210.	0.89	7.8	1.4	1.0	.31
298S	03-585	F	B	69120	398	10.4	2.3	24.	21	23.	240.	0.85	8.9	1.3	0.97	.29
455B	01-883	M	G	71106	402	11.7	2.2	26.	22	19.	220.	0.70	8.1	1.1	0.83	.23
471A	01-947	M	K	71225	397	7.5	1.3	9.6	23	19.	150.	0.70	5.5	1.2	0.80	.22
453T	02-883	F	H	71106	408	6.4	1.7	11.	24	18.	110.	0.67	4.1	1.0	0.75	.20
315U	01-594	F	D	69148	397	8.3	1.9	16.	25	18.	150.	0.67	5.5	1.0	0.77	.21
304S	01-585	F	B	69120	386	7.4	1.3	9.6	26	17.	120.	0.63	4.4	0.98	0.72	.21
311B	03-593	M	C	69147	400	9.3	0.74	7.0	27	14.	130.	0.52	4.8	0.79	0.57	.16
328T	02-641	F	F	69212	385	10.6	0.96	10.	28	13.	140.	0.48	5.2	0.76	0.55	.15
467A	03-916	M	I	71175	373	12.2	0.96	11.	29	13.	160.	0.48	5.9	0.77	0.55	.14
467T	04-946	F	L	71224	422	6.4	0.67	4.4	30	13.	81.	0.48	3.0	0.78	0.55	.17
297B	02-585	M	A	69120	401	9.6	1.9	18.	31	12.	110.	0.44	4.1	0.68	0.45	.14
326C	01-641	M	E	69212	391	9.4	0.67	6.3	32	12.	110.	0.44	4.1	0.70	0.51	.14
463A	02-916	M	I	71175	411	10.9	0.74	8.1	33	12.	130.	0.44	4.8	0.74	0.50	.14
480B	03-946	M	K	71224	372	8.2	0.74	6.3	34	11.	91.	0.41	3.4	0.68	0.46	.14
454S	04-882	F	H	71105	401	9.6	1.5	14.	35	10.	95.	0.37	3.5	0.60	0.44	.12
454E	03-882	M	G	71105	401	8.9	0.78	7.0	36	9.8	87.	0.36	3.2	0.60	0.42	.12
305V	02-584	F	B	69119	382	6.9	0.67	4.4	37	9.8	67.	0.36	2.5	0.57	0.37	.10
460T	04-916	F	J	71175	418	7.4	1.1	12.	38	9.5	70.	0.35	2.6	0.56	0.42	.12
327B	01-640	M	E	69211	385	9.0	0.59	5.2	39	8.0	72.	0.30	2.7	0.46	0.32	.09
323V	02-640	F	F	69211	408	7.8	0.44	3.4	40	7.8	60.	0.29	2.2	0.45	0.33	.09
303B	03-584	M	A	69119	389	6.7	0.63	4.4	41	7.6	51.	0.28	1.9	0.44	0.34	.12
310S	02-593	F	D	69147	420	9.1	0.35	3.2	42	6.3	57.	0.23	2.1	0.36	0.26	.07
469S	02-946	F	L	71224	397	7.2	0.48	3.4	43	5.8	42.	0.21	1.6	0.35	0.26	.08
478B	01-946	M	K	71224	379	9.6	0.37	3.7	44	5.7	54.	0.21	2.0	0.33	0.26	.08
308B	01-593	M	C	69147	402	10.3	0.27	2.8	45	5.4	55.	0.20	2.0	0.31	0.23	.06
454C	01-882	M	G	71105	401	9.5	0.52	4.8	46	5.4	51.	0.20	1.9	0.32	0.24	.06
464T	01-916	F	J	71175	384	7.4	0.44	3.2	47	5.0	37.	0.19	1.4	0.29	0.21	.05
455T	02-882	F	H	71105	401	10.4	0.59	6.3	48	4.9	51.	0.18	1.9	0.30	0.21	.05
313S	01-598	F	D	69160	411	7.9	0.30	2.4	49	2.4	19.	0.089	0.70	0.14	0.098	.02

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BETA RADIATION DOSE TO LUNG

DOSE RATE (GY/DAY)			CUMULATIVE DOSE (GY)						
60 DAYS	365 DAYS	AT DEATH	60 DAYS	365 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
2.7		1.3	190.		890. +	530.	70030	246	D-PULMONARY INJURY
2.9		1.5	200.		1000. +	570.	69355	234	D-PULMONARY INJURY
2.4		0.99	170.		840. +	500.	70121	273	D-PULMONARY INJURY
1.9	.57	0.12	140.	470.	620. +	590.	73284	790	E-HEMANGIOSARCOMA,LUNG
2.3		0.91	150.		710. +	500.	70127	279	D-PULMONARY INJURY
2.0	.60	0.15	140.	500.	660. +	610.	71141	750	E-HEMANGIOSARC. AND FIBROSARC ,LUNG
2.0		0.69	140.		530. +	410.	72135	275	D-PULMONARY INJURY
1.8		0.91	120.		460. +	280.	71361	185	D-PULMONARY INJURY
1.8		0.66	120.		570. +	410.	72122	311	D-PULMONARY INJURY
1.5	.43	0.032	110.	360.	470. +	460.	72194	1077	E-HEMANGIOSARCOMA,LUNG
1.3	.43	0.060	95.	330.	460. +	430.	71335	916	D-HEMANGIOSARC. AND B-A-CARCINOMA,LUNG
1.4	.38		100.	340.	440.	440.	75334	2313	D-HEM-SARC.,SITE UND.;B-A-CARC.,LUNG
1.4		0.74	98.		390. +	240.	69314	193	D-PULMONARY VASCULAR INJURY
1.4	.31	0.012	98.	310.	380.	380.	74238	1228	D-PULMONARY THROMBOSIS;AMYLOIDOSIS
1.3	.41	0.018	89.	330.	440. +	430.	74236	1226	D-HEM-SARC.-B-A-CARC.-BRONCHO.CA.,LUNG
1.1	.29	0.0030	80.	260.	330.	330.	75238	1523	D-BRONCHIOLOALVEOLAR CARCINOMA
1.1	.33	0.079	77.	270.	360. +	340.	71183	765	E-HEMANGIOSARCOMA,LUNG
0.97	.27		72.	230.	300.	300.	76160	1810	D-MIXED TUMOR,LUNG;B-A-CARCINOMA
1.0	.29	0.0091	73.	250.	320.	320.	75017	1253	E-SQUAMOUS CELL CARCINOMA,NASAL CAVITY
1.0	.31	0.0015	72.	250.	340.	340.	74217	1895	D-HEMANGIOSARCOMA,SPLEEN
0.97	.29		68.	230.	320.	320.	77199	3001	E-MIXED TUMOR,LUNG; OSTEOSARCOMA,LUNG
0.83	.23		58.	200.	260.	260.	77093	2179	D-EPILEPSY
0.80	.22		57.	190.	250.	250.	77216	2183	E-HEMANGIOSARCOMA,BONE
0.75	.20		53.	180.	230.	230.	78277	2728	E-HEMANGIOSARCOMA,SPLEEN
0.77	.21		54.	180.	240.	240.	80092	3961	D-ADENOCARCINOMA,LUNG
0.72	.21	0.00018	50.	170.	230.	230.	75256	2327	D-HEMANGIOSARCOMA,LIVER
0.57	.16	0.00060	40.	140.	180.	180.	74295	1974	E-HEMANGIOSARCOMA,BOTH HUMERI
0.55	.15		39.	130.	170.	170.	79365	3805	E-GASTROENTEROPATHY
0.55	.14		39.	13.	160.	160.	76112	1763	D-HEMANGIOSARCOMA,TBLN
0.55	.17		39.	140.	180.	180.	76147	1749	D-ACCIDENTAL DEATH
0.45	.14		33.	110.	150.	150.	76065	2501	D-PLEURITIS (NOCARDIA SP.)
0.51.	.14		36.	120.	160.	160.	78205	3280	E-HEMANGIOSARCOMA,TBLN
0.50	.14		36.	120.	150.	150.	79102	2849	D-HEMANGIOSARCOMA,HEART
0.46	.14		33.	110.	150.	150.	82125	3919	E-HEMANGIOSARC.,TBLN;CARCINOMA,LUNG
0.44	.12	0.0013	31.	100.	130.	130.	75171	1527	D-HEMANGIOSARCOMA,HEART
0.42	.12		30.	100.	130.	130.	77278	2365	E-HEMANGIOSARCOMA,DERMIS
0.37	.10		46.	120.	120.	120.	85021	5746	D-CARCINOMA,SKIN
0.42	.12		29.	100.	130.	130.	80189	3301	E-CHRONIC TRACHITIS
0.32	.097		23.	78.	110.	110.	82316	4853	E-CARCINOMA,LUNG
0.33	.092	0.00010	23.	79.	100.	100.	75127	2107	D-HEMANGIOSARCOMA,TBLN
0.34	.12		23.	86.	120.	120.	76133	2570	E-HEMANGIOSARCOMA,LIVER
0.26	.077		18.	63.	85.	85.	81049	4285	E-CARCINOMA,LUNG
0.26	.080		18.	64.	86.	86.	83235	4394	E-INTERSTITIAL NEPHRITIS;LUNG CARC.
0.26	.083		18.	64.	87.	87.	78169	2502	D-HEMANGIOSARCOMA,TBLN
0.23	.00028		16.	57.	77.	77.	82342	4943	D-MYOCARDIAL DEGENERATION;LUNG TUMOR
0.24	.067		17.	57.	78.	78.	78301	2753	E-HEMANGIOSARCOMA,DISSEMINATED
0.21	.053		15.	48.	62.	62.	82112	3955	D-PYOMETRA AND HEMANGIOMA,TBLN
0.21	.050		15.	47.	60.	60.	76072	1793	E-HEMANGIOSARCOMA,SITE UNDETERMINED
0.098	.029		7.0	24.	32.	32.	79257	3749	D-HEMANGIOSARCOMA,TBLN

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(2)

BETA RADIATION DOSE TO LUNG

	DOSE RATE (GY/DAY)			CUMULATIVE DOSE (GY)						
ITIAL	60 DAYS	365 DAYS	AT DEATH	60 DAYS	365 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
12	0.089	.028		6.2	22.	30.	30.	81162	4410	D-CONGEST. HEART FAIL.;CARCINOMA,LUNG
11	0.086	.025		5.9	21.	27.	27.	85238	5178	E-ADENOCARCINOMA,MAMMARY GLAND
10	0.079	.025		5.4	19.	26.	26.	76083	2479	D-PERITONITIS (NOCARDIA SP.)
92	0.068	.022		4.7	17.	23.	23.	79324	3841	E-ADENOCARCINOMA,BLADDER
83	0.067	.021		4.5	17.	22.	22.	82160	4698	E-CARCINOMA,LUNG
73	0.059	.019		3.9	15.	20.	20.	79132	3574	D-UNDETERMINED
71	0.052	.016		3.6	13.	17.	17.	80291	3404	E-LYMPHOSARCOMA,DISSEMINATED
67	0.050	.014		3.5	12.	16.	16.	86261	5517	E-PYELONEPHRITIS
66	0.050	.013		3.4	12.	15.	15.	87114	5735	E-NEPHRITIS,KIDNEY
41	0.030	.0096		2.1	7.5	10.	10.	81096	4266	E-HEMANGIOSARCOMA,SPLEEN
37	0.028	.0084		1.9	6.8	9.1	9.1	82285	4199	E-CARCINOMA,THYROID
37	0.023	.0068		1.6	5.6	7.4	7.4	86095	5400	D-CARCINOMA,MAMMARY
40	0.024	.0072		1.7	5.9	7.7	7.7	84201	4845	E-ADENOCARCINOMA,MAMMARY GLAND
26	0.018	.0051		1.3	4.3	5.7	5.7	84226	5547	E-ADENOCARCINOMA,MAMMARY GLAND
24	0.018	.0049		1.2	4.2	5.5	5.5	76260	2682	D-TRANSITIONAL CELL CARCINOMA,BLADDER
21	0.015	.0042		1.1	3.6	4.7	4.7	81127	4353	E-CAR.,KID.;LYMPHOSAR,SPLEEN;CAR.,LUNG
22	0.015	.0048		1.1	3.8	5.0	5.0	81215	3694	E-PERINEAL HERNIA
19	0.014	.0044		0.96	3.4	4.7	4.7	83210	5113	D-HEMANGIOSARCOMA,SPLEEN
18	0.014	.0047		0.94	3.5	4.8	4.8	86030	5286	D-BRONCHIOLITIS
14	0.011	.0034		0.74	2.7	3.6	3.6	84154	4679	D-SPONDYLITIS,ACUTE
11	0.0080	.0023		0.57	1.9	2.5	2.5	82071	4685	E-NECROTIZING PNEUMONIA
11	0.0087	.0030		0.58	2.2	3.1	3.1	83113	4392	E-CARCINOMA,MAMMARY GLAND
11	0.0078	.0026		0.52	2.0	2.7	2.7	83187	4466	E-PITUITARY TUMOR
95	0.0074	.0021		0.50	1.8	2.3	2.3	88150	6137	D-MUSCLE ABSCESSATION
71	0.0056	.0016		0.38	1.3	1.7	1.7	81083	4337	E-NECROTIZING HEPATITIS;CARC.,LUNG
49	0.0038	.0011		0.26	0.93	1.2	1.2	82096	3941	E-ADENOCARCINOMA,PROSTATE
47	0.0037	.0011		0.25	0.88	1.1	1.1	85110	5002	D-ENTERITIS
46	0.0036	.0010		0.24	0.86	1.1	1.1	79054	3578	E-PERIPHERAL NERVE TUMOR
45	0.0035	.0010		0.24	0.85	1.1	1.1	79323	3818	E-CARCINOMA,MAMMARY GLAND
37	0.0029	.00083		0.19	0.69	0.90	0.90	80252	3366	D-PYOMETRA
34	0.0026	.00076		0.18	0.64	0.82	0.82	86041	5417	D-BRONCHOPNEUMONIA
30	0.0024	.00068		0.16	0.57	0.74	0.74	84227	5548	E-NEPHRITIS,CHRONIC
26	0.0020	.00059		0.14	0.49	0.64	0.64	85093	5808	E-INTERSTITIAL NEPHRITIS
24	0.0019	.00055		0.13	0.46	0.59	0.59	86152	6205	D-EPILEPSY
23	0.0018	.00052		0.12	0.44	0.56	0.56	83100	5004	D-CARCINOMA,LUNG
20	0.0015	.00044		0.10	0.37	0.48	0.48	84054	5404	E-MENINGIOMA,BRAIN
15	0.0012	.00033		0.079	0.28	0.36	0.36	85149	5837	E-INTERSTITIAL NEPHRITIS
12	0.00093	.00027		0.063	0.22	0.29	0.29	78276	2612	D-ACCIDENTAL DEATH
11	0.00083	.00024		0.057	0.20	0.26	0.26	86189	5496	E-DISC PROTRUSION
11	0.00083	.00024		0.057	0.20	0.26	0.26	83110	4390	E-CARCINOMA,TONSIL
095	0.00074	.00021		0.050	0.18	0.23	0.23	80279	4087	D-CONGESTIVE HEART FAILURE
083	0.00065	.00019		0.044	0.16	0.20	0.20	83007	4218	E-PITUITARY TUMOR
057	0.00044	.00013		0.030	0.11	0.14	0.14	83215	5119	D-HEPATIC DEGENERATION
054	0.00043	.00012		0.029	0.10	0.13	0.13	82353	4150	D-CHRONIC ENTERITIS
037	0.00029	.000084		0.020	0.071	0.091	0.091	84355	5624	E-CONGESTIVE HEART FAILURE
018	0.00014	.000040		0.0094	0.034	0.043	0.043	85253	5264	E-INTERSTITAL NEPHRITIS
014	0.00011	.000032		0.0075	0.027	0.035	0.035	86154	5530	D-PULMONARY FIBROSIS
								80261	4151	D-HEMOLYTIC ANEMIA
								83247	5233	D-CHRONIC PANCREATITIS
								80323	4184	D-MAST CELL TUMOR,SPLEEN
								82025	4617	D-HYPERADRENOCORTICISM
								83299	5203	D-TRANISITIONAL CELL CARC.,BLADDER
								84100	5369	E-NEPHRITIS,CHRONIC
								85042	5057	E-ANKYLOSING SPONDYLITIS
								82276	4195	D-ADENOCARCINOMA,STOMACH
								83180	4394	E-CARCINOMA,LUNG
								83082	4296	E-LYMPHOSARCOMA,GENERALIZED
								86020	5281	E-HEART,CHRONIC.INFARCTION
								84122	4652	E-ASTROCYTOMA,BRAIN

RE INCLUDED.

A.10 ^{144}Ce in Fused Aluminosilicate Particles, Longevity Study (Series II) (continued)

DOG IDENTIFICATION			INHALATION EXPOSURE				I.^.B.		I.L.B.					DO	
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	D
296B	01-592	M	A	69135	418	10.0	0.14	1.4	50	2.1	21.	0.078	0.78	0.12	0.
466V	04-915	F	J	71174	380	7.9	0.17	1.3	51	2.0	15.	0.074	0.55	0.11	0.
313C	02-598	M	C	69160	411	9.6	0.14	1.4	52	1.8	17.	0.067	0.63	0.10	0.
304T	02-592	F	B	69135	401	7.8	0.093	0.70	53	1.6	12.	0.059	0.44	0.092	0.
324V	03-638	F	F	69210	402	7.2	0.14	1.0	54	1.5	11.	0.056	0.41	0.083	0.
331A	04-638	M	E	69210	370	9.0	0.081	0.74	55	1.3	11.	0.048	0.41	0.073	0.
461B	03-915	M	I	71174	417	11.1	0.11	1.2	56	1.2	13.	0.044	0.48	0.071	0.
467U	04-945	F	L	71223	421	6.6	0.10	0.67	57	1.2	7.5	0.044	0.28	0.067	0.
477A	03-945	M	K	71223	380	11.0	0.067	1.1	58	1.1	12.	0.041	0.44	0.066	0.
329C	03-642	M	E	69213	386	8.3	0.044	0.37	59	0.71	5.9	0.026	0.22	0.041	0.
453B	03-881	M	G	71104	406	8.1	0.052	0.44	60	0.63	5.1	0.023	0.19	0.037	0.
463S	02-915	F	J	71174	410	10.4	0.028	0.30	61	0.53	5.5	0.020	0.20	0.037	0.
452U	04-881	F	H	71104	416	8.2	0.17	1.4	62	0.52	4.2	0.019	0.16	0.040	0.
314S	04-597	F	D	69157	407	9.7	0.030	0.29	63	0.45	4.4	0.017	0.16	0.026	0.
296U	02-591	F	B	69134	417	8.4	0.030	0.25	64	0.44	3.7	0.016	0.14	0.024	0.
313B	03-597	M	C	69157	408	10.1	0.041	0.41	65	0.37	3.7	0.014	0.14	0.021	0.
461A	01-915	M	I	71174	417	12.0	0.018	0.22	66	0.35	4.3	0.013	0.16	0.022	0.0
322V	02-638	F	F	69210	409	6.4	0.026	0.16	67	0.32	2.0	0.012	0.074	0.019	0.0
476C	01-945	M	K	71223	387	9.0	0.021	0.19	68	0.30	2.7	0.011	0.10	0.018	0.0
471S	02-945	F	L	71223	395	6.3	0.033	0.21	69	0.25	1.6	0.0093	0.059	0.014	0.0
297A	01-591	M	A	69134	415	11.0	0.014	0.16	70	0.18	2.0	0.0067	0.074	0.011	0.0
453U	02-881	F	H	71104	406	5.8	0.016	0.089	71	0.18	1.1	0.0067	0.041	0.011	0.0
457B	01-881	M	G	71104	374	8.3	0.014	0.11	72	0.17	1.4	0.0063	0.052	0.011	0.0
472W	02-942	F	L	71222	390	8.0	0.013	0.11	73	0.16	1.3	0.0059	0.048	0.0095	0.0
298U	02-590	F	B	69129	407	9.4	0.013	0.13	74	0.12	1.2	0.0044	0.044	0.0071	0.0
462C	02-914	M	I	71173	409	9.0	0.0059	0.052	75	0.083	0.75	0.0031	0.028	0.0049	0.0
476B	01-942	M	K	71222	386	8.5	0.0041	0.036	76	0.079	0.67	0.0029	0.025	0.0047	0.0.
303S	02-589	F	B	69128	398	8.9	0.0085	0.078	77	0.077	0.68	0.0028	0.025	0.0046	0.0
308U	01-597	F	D	69157	412	10.1	0.0048	0.048	78	0.076	0.77	0.0028	0.028	0.0045	0.0
464S	01-914	F	J	71173	382	8.1	0.0044	0.037	79	0.062	0.50	0.0023	0.019	0.0037	0.0
451T	04-880	F	H	71103	415	8.0	0.0033	0.026	80	0.057	0.45	0.0021	0.017	0.0034	0.0
310A	02-597	M	C	69157	430	11.5	0.0078	0.089	81	0.051	0.59	0.0019	0.022	0.0030	0.0
304A	01-590	M	A	69129	395	11.3	0.0056	0.063	82	0.044	0.50	0.0016	0.019	0.0026	0.0
310U	03-596	F	D	69156	429	8.0	0.011	0.089	83	0.041	0.33	0.0015	0.012	0.0024	0.0
323T	05-636	F	F	69209	386	8.4	0.0056	0.044	84	0.039	0.33	0.0014	0.012	0.0023	0.0
306A	01-589	M	A	69128	389	9.5	0.0070	0.063	85	0.033	0.31	0.0012	0.011	0.0020	0.0
312A	04-596	M	C	69156	406	11.0	0.0018	0.020	86	0.025	0.27	0.00092	0.010	0.0015	0.0
472U	02-941	F	L	71221	389	8.5	0.0013	0.011	87	0.020	0.17	0.00074	0.0063	0.0012	0.0
465B	01-912	M	I	71172	378	11.2	0.0015	0.017	88	0.018	0.20	0.00067	0.0074	0.0011	0.0
450D	03-880	M	G	71103	419	11.1	0.0025	0.027	89	0.018	0.20	0.00067	0.0074	0.0011	0.0
327D	06-636	M	E	69209	383	8.7	0.0029	0.025	90	0.016	0.14	0.00059	0.0052	0.00095	0.0
462S	02-912	F	J	71172	408	8.1	0.0015	0.012	91	0.014	0.11	0.00052	0.0041	0.00083	0.0
327C	03-636	M	E	69209	383	9.4	0.0023	0.021	92	0.0096	0.090	0.00036	0.0033	0.00057	0.0
478C	01-941	M	K	71221	376	8.9	0.00092	0.0081	93	0.0092	0.081	0.00034	0.0030	0.00054	0.0
324T	04-636	F	F	69209	401	10.8	0.0020	0.021	94	0.0063	0.068	0.00023	0.0025	0.00037	0.0
453A	01-880	M	G	71103	405	9.0	0.00019	0.0017	95	0.0030	0.027	0.00011	0.0010	0.00018	0.0
452T	02-880	F	H	71103	415	9.4	0.00007	0.0067	96	0.0024	0.023	0.000089	0.00085	0.00014	0.0
303V	01-588	F	B	69127	397	7.5			C						
306D	02-588	M	A	69127	388	9.4			C						
308T	02-596	F	D	69156	411	9.3			C						
310B	01-596	M	C	69156	429	11.0			C						
322U	02-636	F	F	69209	408	6.8			C						
324B	01-636	M	E	69209	401	8.8			C						
450A	01-878	M	G	71099	415	11.8			C						
452S	02-878	F	H	71099	411	10.2			C						
464U	02-911	F	J	71169	378	8.9			C						
467B	01-911	M	I	71169	367	6.9			C						
477B	01-940	M	K	71218	375	8.7			C						
479T	02-940	F	L	71218	372	8.0			C						

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABECQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE INCLU

A.11 ^{144}Ce in Fused Aluminosilicate Particles, Sacrifice Study (Series II, III, IV)

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					DOSE RATE (GY/		
TATTOO	AN-EXPT	SEX	SER	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS	120 DAYS
541S	01-999	F	II	72103	395	7.9	5.2	41.	01	71	560	2.6	21.	4.1	3.1	2.3
520A	02-998	M	II	72102	427	11.0	4.8	52.	02	66	720	2.4	27.	3.7	2.8	2.1
530C	04-1007	M	II	72115	417	9.2	5.2	48.	03	64	590	2.4	22.	3.7	2.6	2.1
530B	01-1002	M	II	72109	411	9.5	3.4	32.	04	60	560	2.2	21.	3.4	2.2	
525W	01-1004	F	II	72111	428	7.3	4.1	30.	05	58	420	2.1	16.	3.4	2.5	1.9
527A	03-1007	M	II	72115	418	9.2	2.9	27.	06	54	500	2.0	19.	3.1	2.1	1.6
521T	03-998	F	II	72102	426	8.7	3.4	30.	07	52	450	1.9	17.	3.1	2.4	1.8
526A	01-1001	M	II	72108	416	7.5	3.6	27.	08	52	390	1.9	14.	3.0	2.0	
526B	02-1000	M	II	72104	412	5.8	4.4	25.	09	52	300	1.9	11.	3.1	2.2	1.6
526S	01-1007	F	II	72115	423	6.6	3.7	25.	10	51	330	1.9	12.	2.9	2.1	
525T	02-1003	F	II	72110	427	8.8	4.1	37.	11	48	420	1.8	16.	2.9	2.1	1.6
522T	03-1003	F	II	72110	432	8.0	5.2	41.	12	48	380	1.8	14.	2.9	2.1	1.6
525U	02-1004	F	II	72111	428	9.1	3.3	30.	13	46	420	1.7	16.	2.8	1.9	1.4
539A	03-997	M	II	72101	394	9.3	4.4	41.	14	41	380	1.5	14.	2.4	1.8	1.3
530A	04-998	M	II	72102	404	11.5	3.1	35.	15	39	450	1.4	17.	2.3	1.8	1.3
541U	01-1000	F	II	72104	396	7.9	2.3	18.	16	35	280	1.3	10.	2.1	1.4	1.1
535C	03-1000	M	II	72104	399	7.7	2.6	20.	17	34	260	1.3	9.6	2.0	1.4	1.1
539D	04-1000	M	II	72104	397	7.9	1.9	15.	18	33	260	1.2	9.6	1.9	1.4	1.0
522U	01-998	F	II	72102	424	7.8	3.4	27.	19	33	250	1.2	9.3	1.9	1.4	0.99
526C	02-997	M	II	72101	409	6.9	2.5	17.	20	33	230	1.2	8.5	1.9	1.3	0.96
519S	04-1004	F	II	72111	439	8.3	2.7	23.	21	32	270	1.2	10.	1.9	1.4	1.0
524S	02-1001	F	II	72108	425	6.7	2.0	14.	22	32	210	1.2	7.8	1.9	1.3	1.0
522S	04-997	F	II	72101	423	8.7	2.9	25.	23	31	270	1.1	10.	1.8	1.4	1.1
527B	02-1002	M	II	72109	412	9.3	2.1	19.	24	31	290	1.1	11.	1.8	1.3	0.95
532U	02-1007	F	II	72115	413	7.8	1.6	12.	25	31	240	1.1	8.9	1.8	1.3	0.98
521B	03-999	M	II	72103	427	7.6	3.1	24.	26	30	230	1.1	8.5	1.7	1.3	1.0
536T	03-1001	F	II	72108	403	7.6	2.4	19.	27	29	220	1.1	8.1	1.7	1.2	0.88
519T	03-1004	F	II	72111	439	8.7	3.4	29.	28	28	240	1.0	8.9	1.7	1.2	
527D	01-997	M	II	72101	404	7.9	1.7	14.	29	27	220	1.0	8.1	1.6	1.2	0.90
519A	03-1002	M	II	72109	437	8.6	4.1	35.	30	27	230	1.0	8.5	1.6	1.2	0.87
520B	04-1003	M	II	72110	435	11.9	6.7	78.	31	26	310	0.96	11.	1.6	1.2	0.85
523T	02-1008	F	II	72116	435	6.0	1.7	10.	32	26	150	0.96	5.5	1.5	0.99	0.73
543C	04-1004	M	II	72109	399	7.6	1.6	12.	33	26	190	0.96	7.0	1.5	1.1	0.84
520S	01-1003	F	II	72110	435	6.7	2.5	17.	34	24	160	0.89	5.9	1.5	1.1	0.82
526D	02-999	M	II	72103	411	5.5	1.9	10.	35	16	86	0.59	3.2	0.94	0.68	0.51
541A	05-1000	M	II	72104	396	8.3	1.0	8.5	36	16	140	0.59	5.2	0.92	0.67	0.51
538S	04-1001	F	II	72108	402	6.7	0.89	5.9	37	14	95	0.52	3.5	0.83	0.57	0.42
533T	01-1008	F	II	72116	413	5.9	0.74	4.4	38	14	81	0.52	3.0	0.79	0.56	0.41
523S	01-995	F	II	72097	416	8.8			C							
533A	03-995	M	II	72097	394	8.3			C							
538B	02-995	M	II	72097	391	9.3			C							
540T	05-995	F	II	72097	389	5.7			C							
542A	06-995	M	II	72097	388	9.1			C							
542S	04-995	F	II	72097	388	8.2			C							
521S	06-996	F	II	72098	422	8.6			C							
522A	03-996	M	II	72098	420	8.7			C							
522V	01-996	F	II	72098	420	7.8			C							

BETA RADIATION DOSE TO LUNG

Q	DOSE RATE (GY/DAY) INITIAL	60 DAYS	120 DAYS	365 DAYS	AT DEATH	CUMULATIVE DOSE (GY) 60 DAYS	120 DAYS	365 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
.	4.[illegible]	3.1	2.3		2.2	210	370		850+	390	72231	128	S-PULMONARY INJURY
.	3.7	2.8	2.1		1.5	190	340		770+	450	72283	181	S-PULMONARY INJURY
.	3.7	2.6	2.1		1.3	190	330		990+	550	73005	256	S-PULMONARY INJURY
.	3.4	2.2			1.9	170			870+	210	72189	80	S-PULMONARY INJURY
.	3.4	2.5	1.9		1.4	180	310		700+	400	72290	179	S-PULMONARY INJURY
.	3.1	2.1	1.6		0.99	150	260		750+	420	73003	254	E-PULMONARY INJURY
.	3.1	2.4	1.8		1.7	160	290		680+	300	72230	128	S-PULMONARY INJURY
.	3.0	2.0			1.7	150			750+	190	72189	81	S-PULMONARY INJURY
.	3.1	2.2	1.6		1.1	160	270		550+	350	72284	180	S-PULMONARY INJURY
	2.9	2.1			1.9	150			740+	190	72196	81	S-PULMONARY INJURY
.	2.9	[illegible].1	1.6		1.5	150	260		580+	280	72241	131	S-PULMONARY INJURY
.	[illegible]	2.1	1.6		0.99	150	260		760+	430	73002	258	S-PULMONARY INJURY
.	[illegible]	1.9	1.4	.53	0.27	140	240	450	610+	530	73316	571	E-PULMONARY INJURY
.	2.4	1.8	1.3	.48	0.28	120	220	410	560+	470	73249	514	S-PULMONARY INJURY
.	2.3	1.8	1.3		0.62	120	220		510+	370	73025	289	D-PULMONARY INJURY
.	2.1	1.4	1.1	.40	0.026	100	180	340	450	450	75101	1093	S-PULMONARY INJURY
.6	2.0	1.4	1.1	.44	0.14	99	170	340	470+	430	74056	683	D-PULMONARY INJURY
.6	1.9	1.4	1.0	.39	0.099	96	170	330	430	410	74113	740	S-PULMONARY INJURY
.3	1.9	1.4	0.99		0.94	96	170		350+	170	72230	128	S-PULMONARY INJURY
.5	1.9	1.3	0.96	.35	0.19	94	160	310	400+	350	73250	515	S-PULMONARY INJURY
.	1.9	1.4	1.0	.38	0.025	98	170	330	430	430	75106	1091	S-PULMONARY INJURY
.8	1.9	1.3	1.0	.42	0.059	93	160	330	450+	430	74294	917	S-PULMONARY INJURY
.	1.8	1.4	1.1		0.57	95	170		400+	280	72357	256	S-PULMONARY INJURY
.	1.8	1.3	0.95	.33	0.0046	92	160	300	390	390	76153	1505	D-HEMANGIOSARCOMA,LUNG
.9	1.8	1.3	0.98	.36		91	160	310	410	410	78145	2222	E-HEMANGIOSARCOMA,HEART
.5	1.7	1.3	1.0	.39	0.028	92	160	320	430	430	75106	1099	S-HEMANGIOSARCOMA,LUNG
.1	1.7	1.2	0.88		0.50	86	150		390+	240	73002	260	S-PULMONARY INJURY
.9	1.7	1.2			0.86	86			330+	160	72241	130	S-PULMONARY INJURY
.1	1.6	1.2	0.90	.36	0.22	84	150	290	410+	330	73257	522	D-PULMONARY INJURY
.5	1.6	1.2	0.87	.33	0.042	81	140	280	370+	350	74295	917	S-PULMONARY INJURY
.	1.6	1.2	0.85	.29	0.054	82	140	270	360+	340	74267	888	D-PULMONARY INJURY
.5	1.5	0.99	0.73	.29	0.17	73	120	240	320+	270	73264	514	S-PULMONARY INJURY
0	1.5	1.1	0.84	.34		78	140	270	360	360	80144	2957	E-HEMANGIOSARCOMA,LUNG
.9	1.5	1.1	0.82	.31	0.073	76	130	260	340+	320	74114	735	S-PULMONARY INJURY
.2	0.94	0.68	0.51	.20	0.052	48	83	160	220+	200	74114	742	S-PULMONARY INJURY
.2	0.92	0.67	0.51	.19	0.052	47	82	160	220+	200	74113	740	S-PULMONARY INJURY
5	0.83	0.57	0.42	.16		41	71	140	130	180	84350	4625	D-CARCINOMA.LUNG
0	0.79	0.56	0.41	.16		40	69	130	180	180	82303	3840	D-INTERSTITIAL PNEUMONIA
											72354	257	S-NORMAL
											72224	127	S-NORMAL
											86171	5188	E-ENTERITIS
											83298	4219	D-PULMONARY THROMBOSIS
											74108	742	S-NORMAL
											85316	4968	E-NEPHROSCLEROSIS
											86122	5138	E-LYMPHOSARCOMA, GENERALIZED
											79104	2563	D-MYOCARDIAL INFARCT
											75104	1102	S-NORMAL

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A.11 ^{144}Ce in Fused Aluminosilicate Particles, Sacrifice Study (Series II, III, IV) (continued)

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					BETA RADIATIO DOSE RATE (GY/DAY)				
TATTOO	AN-EXPT	SEX	SER	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS	120 DAYS	365 DAYS	AT DEATH
530S	05-996	F	II	72098	400	8.6			C									
540B	04-996	M	II	72098	390	8.0			C									
547B	02-996	M	II	72098	378	10.4			C									
538A	03-1016	M	III	72137	428	9.1	3.5	32.	01	69	630	2.6	23.	3.8	2.9	2.2		1.4
540U	01-1013	F	III	72132	424	6.6	5.5	37.	02	59	390	2.2	14.	3.4	2.6	1.9		1.3
535T	01-1015	F	III	72136	431	6.3	9.3	59.	03	50	320	1.9	12.	2.6	1.8	1.3		0.65
535B	03-1019	M	III	72144	438	7.8	5.2	41.	04	50	390	1.9	14.	2.9	2.2	1.7		1.6
540S	04-1019	F	III	72144	435	6.5	8.1	52.	05	50	320	1.9	12.	2.7	2.1	1.6		1.4
539B	02-1014	M	III	72133	426	8.6	3.5	30.	06	48	410	1.8	15.	2.7	2.0	1.5		0.51
542C	03-1014	M	III	72133	424	7.8	4.8	37.	07	48	380	1.8	14.	2.2	1.5	1.1	.39	0.042
547C	02-1015	M	III	72136	416	9.9	2.8	28.	08	25	340	0.93	13.	2.0	1.4	1.1	.42	0.039
535A	01-1019	M	III	72144	438	7.9	3.7	30.	09	34	270	1.3	10.	1.9	1.4	1.0		0.92
547T	04-1014	F	III	72133	413	7.1	3.1	22.	10	32	230	1.2	8.5	1.8	1.2	0.93	.37	
544T	02-1019	F	III	72144	432	7.4	3.7	28.	11	32	230	1.2	8.5	1.8	1.3	0.95		0.84
530T	04-1016	F	III	72137	439	10.2	2.7	27.	12	29	300	1.1	11.	1.6	1.2	0.92	.38	0.17
527C	06-1017	M	III	72140	443	10.2			C									
541W	04-1017	F	III	72140	432	8.7			C									
544U	05-1017	F	III	72140	429	7.0			C									
547D	01-1017	M	III	72140	420	7.3			C									
539C	01-1018	M	III	72143	436	8.5			C									
541T	02-1018	F	III	72143	435	8.4			C									
539T	03-1013	F	IV	72132	425	8.6	4.4	37.	01	41	350	1.5	13.	2.2	1.8	1.4	.57	0.56
543A	04-1013	M	IV	72132	422	10.8	3.1	34.	02	33	250	1.2	9.3	1.9	1.4	1.1	.39	0.065
541V	02-1016	F	IV	72137	429	7.8	2.6	20.	03	33	260	1.2	9.6	1.9	1.3	1.0	.41	0.016
542B	01-1016	M	IV	72137	428	9.7	4.1	41.	04	32	320	1.2	12.	1.9	1.2	0.83	.32	
543B	01-1014	M	IV	72133	423	9.2	1.6	15.	05	31	290	1.1	11.	1.8	1.3	0.94	.33	
543S	02-1013	F	IV	72132	422	9.2	3.7	35.	06	29	270	1.1	10.	1.5	1.1	0.87	.34	0.016
530U	03-1017	F	IV	72140	442	8.5			C									
538C	07-1017	M	IV	72140	434	7.5			C									
539S	02-1017	F	IV	72140	433	7.6			C									

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE INCLUDED.

BETA RADIATION DOSE TO LUNG

DOSE RATE (GY/DAY)					CUMULATIVE DOSE (GY)							
INITIAL	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
										75014	1012	S-NORMAL
										74108	741	S-NORMAL
										85031	4682	E-ADENOCARCINOMA,PROSTATE
3.8	2.9	2.2		1.4	200	350		820+	520	72350	213	S-PULMONARY INJURY
3.4	2.6	1.9		1.3	180	310		720+	430	72329	197	D-PULMONARY INJURY
2.6	1.8	1.3		0.65	130	220		620+	410	73089	319	S-PULMONARY INJURY
2.9	2.2	1.7		1.6	150	270		670+	310	72286	142	S-PULMONARY INJURY
2.7	2.1	1.6		1.4	140	250		600+	290	72286	142	S-PULMONARY INJURY
2.7	2.0	1.5		0.51	140	250		590+	460	73124	357	S-PULMONARY INJURY
2.2	1.5	1.1	.39	0.042	110	180	350	450	450	75012	975	D-PULMONARY INJURY
2.0	1.4	1.1	.42	0.039	99	170	340	440	440	75035	995	E-PULMONARY INJURY
1.9	1.4	1.0		0.92	97	170		380+	190	72287	143	S-PULMONARY INJURY
1.8	1.2	0.93	.37		90	150	300	400	400	76334	1662	D-PULMONARY INJURY
1.8	1.3	0.95		0.84	92	160		340+	180	72287	143	S-PULMONARY INJURY
1.6	1.2	0.92	.38	0.17	84	150	290	410+	360	74018	612	S-PULMONARY INJURY
										76345	1666	S-HEPATIC ATROPHY AND FIBROSIS
										72350	210	S-NORMAL
										75043	999	S-NORMAL
										73127	353	S-NORMAL
										72292	149	S-NORMAL
										72290	147	S-NORMAL
2.2	1.8	1.4	.57	0.56	120	210	440	590+	440	73133	367	D-PULMONARY INJURY
1.9	1.4	1.1	.39	0.065	98	170	330	450+	420	74297	896	E-PULMONARY INJURY
1.9	1.3	1.0	.41	0.016	94	160	320	440+	430	75316	1275	D-PULMONARY INJURY
1.9	1.2	0.83	.32		88	150	280	360	360	81068	3219	E-CARCINOMA,LUNG
1.8	1.3	0.94	.33		91	160	300	390	390	78096	2155	D-PULMONARY INJURY
1.5	1.1	0.87	.34	0.016	80	140	280	370	370	75226	1190	E-PULMONARY INJURY
										87224	5563	E-CRONIC RENAL DISEASE; B.A. CARC.,LUNG
										86248	5222	E-NEPHROSCLEROSIS
										76122	1443	E-ASPIRATION PNEUMONIA

EXPOSURE.

. PROMINENT FINDINGS ARE INCLUDED.

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A.12 ^{144}Ce in Fused Aluminosilicate Particles, Immature Longevity Study

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					DOSE RATE (G		
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS	[illegible]
1022U	03-1922	F	D	76239	94	3.5	13.	44.	01	140.	480.	5.2	18.	6.1	2.3	
675S	02-1136	F	B	73033	92	2.5	11.	28.	02	120.	310.	4.4	11.	5.2	2.2	
671C	03-1132	M	C	73030	95	3.8	7.0	27.	03	84.	320.	3.1	12.	3.6	1.6	
1027S	02-1925	F	D	76247	86	2.9	11.	32.	04	79.	230.	2.9	8.5	3.4	1.1	.23
1024D	01-1922	M	E	76239	86	3.7	5.5	20.	05	74.	270.	2.7	10.	3.2	1.0	.27
673D	03-1136	M	C	73033	95	2.2	10.	21.	06	73.	160.	2.7	5.9	3.2	0.86	
673C	01-1136	M	C	73033	95	2.1	7.0	14.	07	70.	140.	2.6	5.2	3.0	0.80	.21
672S	01-1133	F	B	73031	94	3.6	7.4	26.	08	64.	230.	2.4	8.5	2.8	0.96	.26
1026A	01-1925	M	E	76247	88	3.4	8.1	27.	09	53.	180.	2.0	6.7	2.3	0.84	.1
672B	03-1133	M	C	73031	94	3.4	9.6	33.	10	52.	180.	1.9	6.7	2.3	0.76	.21
672C	02-1133	M	C	73031	94	3.2	5.5	18.	11	48.	150.	1.8	5.5	2.1	0.69	.18
629A	01-1055	M	A	72221	92	2.8	10.	28.	12	38.	100.	1.4	3.7	1.6	0.63	.11
1019A	02-1921	M	E	76232	91	3.5	7.8	27.	13	38.	130.	1.4	4.8	1.6	0.56	.14
1033T	02-1927	F	D	76267	89	2.6	4.4	11.	14	37.	95.	1.4	3.5	1.5	0.51	.10
1022S	02-1919	F	D	76231	86	3.2	3.0	9.3	15	34.	110.	1.3	4.1	1.6	0.56	.10
675T	02-1137	F	B	73036	95	3.4	5.9	20.	16	28.	92.	1.0	3.4	1.2	0.43	.13
627B	03-1054	M	A	72220	94	3.5	2.0	7.0	17	24.	85.	0.89	3.1	1.0	0.50	.09
673S	01-1135	F	B	73032	94	2.1	1.9	3.7	18	21.	42.	0.78	1.6	0.91	0.28	.07
1021V	01-1921	F	D	76232	88	3.3	1.3	4.4	19	18.	58.	0.67	2.1	0.78	0.25	.05
673A	02-1132	M	C	73030	92	2.9	6.3	17.	20	16.	44.	0.59	1.6	0.69	0.19	.05
672A	01-1132	M	C	73030	93	3.5	1.9	6.7	21	12.	41.	0.44	1.5	0.52	0.17	.04
1033B	01-1927	M	E	76267	89	3.0	1.1	3.4	22	12.	35.	0.44	1.3	0.52	0.18	.03
671S	02-1131	F	B	73029	94	2.8	1.3	3.7	23	11.	30.	0.41	1.1	0.48	0.14	.03
630B	02-1054	M	A	72220	88	2.8	2.6	7.4	24	9.3	26.	0.34	0.96	0.40	0.16	.02
1023S	03-1919	F	D	76231	86	2.4	0.44	1.0	25	6.7	16.	0.25	0.59	0.29	0.094	.01
630A	01-1054	M	A	72220	88	3.8	0.55	2.1	26	6.0	23.	0.22	0.85	0.26	0.12	.02
675B	04-1131	M	C	73029	88	2.7	0.67	1.8	27	5.0	13.	0.19	0.48	0.22	0.060	.01
1016B	01-1919	M	E	76231	97	3.3	0.89	2.9	28	4.9	16.	0.18	0.59	0.21	0.078	.01
673T	03-1131	F	B	73029	91	1.7	0.70	1.2	29	3.2	5.4	0.12	0.20	0.14	0.033	.00
624D	04-1048	M	A	72209	90	2.7	0.31	0.81	30	3.1	8.1	0.11	0.30	0.13	0.051	.00
671B	03-1130	M	C	73026	91	3.0	0.14	0.52	31	1.6	5.9	0.059	0.22	0.069	0.023	.00
1017B	04-1918	M	E	76230	95	4.0	0.16	0.63	32	1.4	5.4	0.052	0.20	0.061	0.022	.00
1018U	03-1918	F	D	76230	95	4.0	0.067	0.27	33	1.0	4.1	0.037	0.15	0.043	0.020	.00
674T	01-1131	F	B	73029	88	2.1	0.17	0.35	34	0.87	1.8	0.032	0.067	0.038	0.0087	.00
1021T	02-1918	F	D	76230	86	3.0	0.056	0.17	35	0.71	2.1	0.026	0.078	0.031	0.0091	.00
623A	03-1048	M	A	72209	91	4.0	0.063	0.24	36	0.28	1.1	0.010	0.041	0.012	0.0063	.00
1018B	01-1918	M	E	76230	95	3.8	0.0078	0.034	37	0.19	0.72	0.0070	0.027	0.0082	0.0027	.00
669U	03-1125	F	B	73019	84	3.0	0.056	0.16	38	0.17	0.50	0.0063	0.019	0.0074	0.0023	.00
668A	02-1125	M	C	73019	93	3.2	0.052	0.16	39	0.14	0.43	0.0052	0.016	0.0061	0.0019	.00
1017S	01-1915	F	D	76229	94	3.2	0.011	0.035	40	0.12	0.38	0.0044	0.014	0.0052	0.0016	.00
671A	02-1130	M	C	73026	91	2.7	0.036	0.096	41	0.089	0.24	0.0033	0.0089	0.0039	0.0012	.00
624C	02-1048	M	A	72209	90	2.9	0.048	0.14	42	0.061	0.18	0.0023	0.0067	0.0027	0.00084	.00
1021A	03-1921	M	E	76232	88	3.9	0.018	0.070	43	0.051	0.20	0.0019	0.0074	0.0022	0.00069	.00
670S	01-1125	F	B	73019	89	1.7	0.048	0.081	44	0.024	0.040	0.00089	0.0015	0.0010	0.00033	.00
624A	01-1048	M	A	72209	90	4.0	0.031	0.12	45	0.013	0.050	0.00048	0.0018	0.00055	0.00017	.00
1033A	02-1926	M	E	76266	88	2.9	0.017	0.0048	46	0.011	0.032	0.00041	0.0012	0.00048	0.00015	.00
1034U	01-1926	F	D	76266	85	2.8	0.0022	0.0059	47	0.0090	0.024	0.00032	0.00090	0.00038	0.00012	.00
671D	01-1130	M	C	73026	91	2.9	0.024	0.067	48	0.0060	0.016	0.00022	0.00060	0.00026	0.000070	.000
669V	03-1124	F	B	73018	90	2.6	0.032	0.081	49	0.0040	0.010	0.00015	0.00040	0.00017	0.000050	.000
623B	01-1046	M	A	72208	90	3.5			C							
668B	01-1124	M	C	73018	92	3.1			C							
669S	02-1124	F	B	73018	90	3.4			C							
1013S	02-1913	F	D	76223	96	2.7			C							
1016A	01-1913	M	E	76223	89	3.4			C							

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE INCLUDED.

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BETA RADIATION DOSE TO LUNG

OSE RATE (GY/DAY)			CUMULATIVE DOSE (GY)					DAYS		
60 DAYS	365 DAYS	AT DEATH	60 DAYS	365 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	TO 9-30 1991	TO DEATH	COMMENT.
2.3		1.6	210.		550. +	270.	76330		91	D-PULMONARY INJURY
2.2		1.4	190.		800. +	250.	73128		95	D-PULMONARY INJURY; CONG.HEART FAIL.
1.6		1.3	140.		490. +	210.	73151		121	D-PULMONARY INJURY; CONG.HEART FAIL.
1.1	.23	C.053	110.	260.	320. +	300.	78254		738	D-HEMANGIOSARCOMA,LUNG
1.0	.27	0.073	100.	260.	330. +	310.	7820'		700	E-HEMANGIOSARCOMA,LUNG
).86		0.78	100.		150. +	110.	73099		66	D-PULMONARY INJURY; CONG.HEART FAIL.
).80	.21	0.13	92.	210.	27C. +	240.	74179		511	D-PULMONARY INJURY
).96	.26	0.090	88.	250.	310. +	290.	74355		689	E-HEMANGIOSARCOMA,LUNG
).84	.16		82.	190.	230.	230.	80100		1314	E-HEMANGIOSARCOMA,LUNG
).76	.21	0.081	78.	200.	250. +	230.	74284		618	E-HEMANGIOSARCOMA,LUNG
).69	.18	0.0044	72.	180.	220.	220.	77302		1732	D-HEMANGIOSARCOMA,SPLEEN
).63	.11		59.	130.	160.	160.	79330		2666	E-HEMANGIOSARCOMA,MUSCLE
).56	.14		50.	130.	180.	180.	80184		1413	D-HEMANGIOSARCOMA,TBLN
).51	.10		50.	120.	140.	140.	86266		3652	E-CARCINOMA,LUNG;HEMANGIOSARCOMA,LUNG
).56	.10		55.	120.	150.	150.	84196		2887	D-PLEURITIS,NOCARDIA
).43	.13	0.0052	40.	110.	150.	150.	76168		1227	E-HEMANGIOSARCOMA,TBLN.
).50	.095		46.	110.	130.	130.	79004		2341	E-HEMANGIOSARCOMA,DISSEMINATED
).28	.072		30.	72.	91.	91.	86125		4841	E-CARCINOMA,ANAL SAC
).25	.051		25.	58.	71.	71.	84123		2813	E-HEMANGIOSARCOMA,TBLN;B.A. CARC.,LUNG
).19	.055		21.	53.	67.	67.	82069		3326	E-LYMPHOSARC.,GENERAL;ADENOCARC.,LUNG
).17	.047	0.0025	17.	45.	57.	57.	77089		1520	D-EPILEPSY; HYPOTHRYROIDISM
).18	.037		17.	41.	51.	51.	84117		2772	E-HEMANGIOSARCOMA,TBLN
.14	.038		14.	36.	46.	46.	84278		4266	E-CARCINOMA,LUNG
).16	.025		15.	33.	40.	40.	85145		4674	D-CARCINOMA,LUNG
.094	.019		9.0	21.	27.	27.	86175		3597	E-CARCINOMA,LUNG
.12	.024		11.	27.	33.	33.	87128		5387	E-CARCINOMA,NASAL
.060	.015		7.0	15.	19.	19.	83212		3835	D-PANCREATIC ATROPHY
.078	.014		6.9	17.	20.			5521		
.033	.0087		3.3	8.1	11.	11.	85361		4715	D-INTERSTITIAL PNEUMONIA
.051	.0089		4.7	11.	13.	13.	87026		5296	E-MELANOMA,ORAL
.023	.0065		2.5	6.3	8.0	8.0	89114		5932	E-MESOTHELIOMA,PULMONARY CARCINOMA
.022	.0054		1.9	5.2	6.6	6.6	90141		5025	E-TRANSITIONAL CELL CARCINOMA,PROSTATE
.020	.0049		1.7	4.5	6.5	6.5	91141		5390	D-INTERSTITIAL NEPHRITIS
.0087	.0023		1.0	2.4	2.9	2.9	89090		5905	E-PAPILLARY ADENOCARCINOMA,LUNG
.0091	.0020		0.89	2.1	2.7	2.7	89095		4614	E-MAMMARY COMPLEX ADENOCARCINOMA
.0063	.0011		0.50	1.3	1.6	1.6	88007		5642	E-HEART BASE TUMOR,HEART
.0027	.00090		0.23	0.67	0.98	0.98	84313		3005	D-FOCAL PNEUMONIA
.0023	.00058		0.24	0.58	0.74	0.74	84291		4289	E-LYMPHOSARCOMA,VISCERAL
.0019	.00046		0.19	0.46	0.59	0.59	88343		5802	E-CORONARY, PULMONARY THROMBOSES
.0016	.00040		0.17	0.40	0.51	0.51	88243		4397	E-DEGENERATIVE MYOPATHY,ESOPHAGUS
.0012	.00030		0.13	0.30	0.38	0.38	84163		4154	D-IMPACTION,GALL BLADDER
.00084	.00021		0.088	0.21	0.27	0.27	81191		3270	E-POLIOENCEPHALOMALACIA, SPINAL CORD
.00069	.00017		0.072	0.17	0.22	0.22	86244		3665	D-LEIOMYOSARCOMA, INTESTINE
.00033	.000082		0.034	0.083	0.11	0.11	87012		5106	E-CHRONIC INTERSTITIAL NEPHRITIS
.00017	.000042		0.018	0.043	0.054	0.054	85225		4765	E-CIRRHOSIS,LIVER
.00015	.000037		0.015	0.044	0.047	0.047	86283		3670	D-PNEUMONIA
.00012	.000029		0.012	0.029	0.037	0.037	90233		5081	E-ADENOCARCINOMA, MAMMARY GLAND
.000070	.000019		0.0080	0.019	0.024	0.024	88061		5513	E-MALIGNANT MELANOMA,ORAL CAVITY
.000050	.000013		0.0060	0.013	0.017	0.017	87242		5338	D-PNEUMONIA
							84027		4202	E-HEART FAILURE
							87267		5362	D-HEART FAILURE
							84214		4213	E-LYMPHOSARCOMA,GENERALIZED
							87220		4015	D-ENDOCARDITIS
							80140		1378	E-VERTEBRAL DISC RUPTURE

INCLUDED.

A.13 ^{144}Ce in Fused Aluminosilicate Particles, Immature Sacrifice Study

DOG IDENTIFICATION			INHALATION EXPOSURE			I.B.B.		I.L.B.				BETA R. DOSE RATE (GY/DAY)			
TATTOO	AN-EXPT	SEX	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS	120 DAYS	365 DAYS
572T	04-1132	F	73030	93	3.0	5.2	15.	46	140	1.7	5.2	2.2	.63	.39	.15
629B	03-1055	M	72221	92	2.7	10.	27.	43	120	1.6	4.4	1.7	.88	.46	
673U	01-1137	F	73036	98	1.7	5.2	8.9	37	62	1.4	2.3	1.2	.42		
631S	03-1063	F	72228	91	1.8	1.4	2.4	11	19	0.41	0.7	0.48	.17	.10	.035

UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDIN

1

BETA RADIATION DOSE TO LUNG

	DOSE RATE (GY/DAY)				CUMULATIVE DOSE (GY)							
ITIAL	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
[illegible].2	.63	.39	.15	.084	69	98	160	200+	170	74179	514	S-PULMONARY INJURY
1.7	.88	.46		.42	75	110		160+	120	72350	129	S-
[illegible].2	.42			.29	44			130+	51	73117	81	S-
[illegible].48	.17	.10	.035		16	24	38	38	38	82258	3241	S-

.ATION EXPOSURE.

IVELY. PROMINENT FINDINGS ARE INCLUDED.

2

A.14 ^{144}Ce in Fused Aluminosilicate Particles, Aged Longevity Study

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					DOSE RATE (GY		
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS	120 DAYS
FD-49	02-982	F	B	72040	3748	9.5	5.5	52.	01	75.	710	2.8	26.	4.4	3.0	2.2
FD-40	02-991	F	E	72055	3565	12.0	6.3	74.	02	67.	800	2.5	30.	4.0	3.2	2.5
FD-98	01-987	F	C	72046	3686	10.9	3.7	41.	03	56.	610	2.1	23.	3.3	2.5	2.0
FD-108	03-987	F	D	72046	3537	11.7	5.9	70.	04	51.	600	1.9	22.	3.0	2.3	1.8
FD-118	01-990	F	F	72054	3318	6.7	7.0	44.	05	50.	330	1.9	12.	3.0	2.2	1.7
FD-145	03-982	F	A	72040	3840	10.5	2.7	28.	06	40.	420	1.5	16.	2.4	1.8	1.4
73B	01-1685	M	H	75252	3814	11.5	5.9	70.	07	37.	420	1.4	16.	2.1	1.6	1.2
176A	02-1689	M	K	75258	3392	11.9	2.3	28.	08	35.	410	1.3	15.	2.0	1.5	1.2
211C	03-1690	M	L	75259	3250	11.3	2.5	28.	09	33.	370	1.2	14.	1.9	1.5	1.2
105A	03-1687	M	I	75254	3677	13.2	2.3	30.	10	32.	420	1.2	16.	1.8	1.4	1.1
151A	03-1688	M	J	75255	3514	13.6	4.4	59.	11	27.	370	1.0	14.	1.5	1.2	0.96
FD-12	02-987	F	C	72046	3714	14.5	4.4	67.	12	27.	400	1.0	15.	1.6	1.1	0.83
71A	02-1686	M	H	75253	3819	13.0	2.6	33.	13	25.	320	0.93	12.	1.4	1.1	0.88
FD-7	01-991	F	E	72055	3511	10.2	4.4	48.	14	25.	250	0.93	9.3	1.5	1.1	0.84
FD-100	01-983	F	B	72041	3841	8.8	3.0	26.	15	23.	200	0.85	7.4	1.4	1.0	0.78
FD-121	02-990	F	F	72054	3119	16.0	3.3	52.	16	23.	360	0.85	13.	1.4	1.0	0.78
FD-94	03-990	F	D	72054	3461	6.7	2.3	15.	17	22.	150	0.81	5.5	1.3	0.98	0.75
FD-31	04-982	F	A	72040	3859	10.7	1.4	14.	18	22.	230	0.81	8.5	1.3	0.95	0.72
FD-103	01-982	F	B	72040	3705	9.4	1.0	9.3	19	20.	190	0.74	7.0	1.2	0.88	0.70
166A	03-1689	M	K	75258	3417	12.2	1.4	18.	20	17.	210	0.63	7.8	0.97	0.75	0.59
1168	02-1688	M	J	75255	3638	10.7	1.4	15.	21	16.	170	0.59	6.3	0.91	0.70	0.55
2140	01-1690	M	L	75259	3218	10.1	1.3	13.	22	16.	170	0.59	6.3	0.91	0.70	0.55
FD-32	03-984	F	D	72045	3542	7.8	1.4	11.	23	14.	110	0.52	4.1	0.83	0.64	0.50
FD-47	02-984	F	C	72045	3585	8.4	1.0	8.9	24	14.	120	0.52	4.4	0.83	0.58	0.44
FD-190	01-1376	M	G	74036	3844	9.7	1.5	14.	25	14.	130	0.52	4.8	0.83	0.58	0.46
FD-15	01-989	F	F	72053	3273	12.3	2.6	31.	26	13.	160	0.48	5.9	0.77	0.57	0.44
FD-30	02-983	F	A	72041	3877	11.4	1.9	21.	27	13.	150	0.48	5.5	0.77	0.62	0.49
23A	03-1374	M	G	74035	3502	14.1	1.9	26.	28	12.	170	0.44	6.3	0.71	0.55	0.4[illegible]
FD-185	02-1374	M	G	74035	3864	11.2	5.5	63.	29	12.	140	0.44	5.2	0.71	0.50	0.[illegible]
FD-153	02-989	F	E	72053	3320	8.6	1.7	15.	30	11.	96	0.41	3.6	0.65	0.49	0.38
FD-154	04-989	F	F	72053	3313	11.4	1.0	11.	31	9.0	100	0.33	3.7	0.53	0.38	0.29
FD-95	01-984	F	C	72045	3563	7.4	0.67	4.8	32	8.5	62	0.31	2.3	0.50	0.37	0.28
116A	01-1588	M	J	75255	3638	11.9	0.63	7.4	33	8.4	100	0.31	3.7	0.48	0.38	0.30
1098	02-1687	M	I	75254	3671	10.9	0.70	7.8	34	8.3	90	0.31	3.3	0.47	0.35	0.26
FD-131	01-1374	M	G	74035	3889	10.6	0.55	5.9	35	8.3	88	0.31	3.3	0.49	0.37	0.29
1658	01-1689	M	K	75258	3419	14.0	0.81	11.	36	8.0	110	0.30	4.1	0.46	0.36	0.28
FD-48	04-984	F	D	72045	3544	12.2	1.3	15.	37	7.7	94	0.28	3.5	0.46	0.34	0.27
FD-38	03-983	F	B	72041	3326	8.7	0.85	7.4	38	7.4	64	0.27	2.4	0.44	0.34	0.27
FD-104	04-983	F	A	72041	3931	12.3	0.89	11.	39	6.4	79	0.24	2.9	0.38	0.27	0.21
181C	02-1690	M	L	75259	3362	10.2	1.6	16.	40	5.9	60	0.22	2.2	0.34	0.26	0.21
FD-150	03-989	F	E	72053	3320	9.9	0.89	8.5	41	5.5	54	0.26	2.0	0.33	0.25	0.20
FD-307	01-1686	M	H	75253	3752	12.9	0.12	1.6	42	2.4	31	0.089	1.1	0.14	0.11	0.087
FD-101	05-981	F	A	72039	3842	9.9			C							
FD-117	01-981	F	C	72039	3679	6.2			C							
FD-147	02-981	F	D	72039	3525	8.9			C							
FD-149	04-981	F	F	72039	3261	8.2			C							
FD-4	03-981	F	E	72039	3499	14.7			C							
FD-6	06-981	F	B	72039	3815	10.6			C							
2C	01-1379	M	G	74038	3777	12.0			C							
111A	05-1684	M	I	75248	3656	9.8			C							
114D	01-1684	M	J	75248	3634	12.1			C							
178A	04-1684	M	K	75248	3380	9.6			C							
2258	02-1684	M	L	75248	3133	12.2			C							
59C	03-1684	M	H	75248	3865	14.9			C							

UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS ARE I

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	BETA RADIATION DOSE TO LUNG												
	DOSE RATE (GY/DAY)					CUMULATIVE DOSE (GY)							
MBQ	INITIAL	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS TO DEATH	COMMENT
26.	4.4	3.0	2.2		1.4	210.	370		760+	500	72237	197	D-PULMONARY INJURY
30.	4.0	3.2	2.5		1.2	210.	380		1100+	740	73009	320	D-PULMONARY INJURY
23.	3.3	2.5	2.0		1.2	170.	310		840+	530	72307	261	D-PULMONARY INJURY
22.	3.0	2.3	1.:8		1.1	160.	280		710+	440	72279	233	E-PULMONARY INJURY
12.	3.0	2.2	1.7		0.87	150.	260		650+	450	72327	273	E-PULMONARY INJURY
16.	2.4	1.8	1.4		0.99	130.	220		560+	330	72249	209	D-PULMONARY INJURY
16.	2.1	1.6	1.2	.43	0.23	110.	200	380	480+	430	77024	503	E-PULMONARY FIBROSIS
15.	2.0	1.5	1.2	.45		110.	190	370	490	490	79078	1281	D-CARCINOMA,LUNG
14.	1.9	1.5	1.2	.45	0.066	100.	180	370	480+	460	78013	850	E-PULMONARY INJURY
16.	1.8	1.4	1.1	.41	0.20	95.	170	340	440+	390	77068	545	D-PULMONARY INJURY
14.	1.5	1.2	0.96	.39	0.37	80.	140	300	400+	300	76264	374	E-PULMONARY INJURY; CONG.HEART FAIL.
15.	1.6	1.1	0.83		0.52	79.	140		300+	200	72260	214	D-PULMONARY INJURY
12.	1.4	1.1	0.88		0.50	75.	130		360+	230	76152	264	D-PULMONARY INJURY
9.3	1.:	1.1	0.84		0.49	74.	130		830+	220	72305	250	D-PULMONARY INJURY; CONG.HEART FAIL.
7.4	1.4	1.0	0.78		0.037	71.	120	240	320+	310	74253	943	D-PULMONARY INJURY
13.	1.4	1.0	0.78		0.45	68.	120		310+	200	72309	255	D-PULMONARY INJURY
5.5	1.3	0.98	0.75	.28	0.017	68.	120	230	310	310	75165	1207	D-PULMONARY INJURY
8.5	1.3	0.95	0.72		0.34	66.	120		270+	200	72320	280	D-PULMONARY INJURY; CONG.HEART FAIL.
7.0	1.2	0.88	0.70		0.25	60.	⁝10	220	290+	220	73064	390	D-PULMONARY INJURY
7.8	0 97	0.75	0.59	.22		52.	92	180	240	240	82110	2409	E-ADENOCARCINOMA,NASAL;CARCINOMA,LUNG
6.3	0.91	0.70	0.55	.21		49.	86	170	230	230	78325	1166	D-HEMORRHAGIC ENTERITIS
6.3	ʌ.91	0.70	0.55	.21		49.	86	170	230	230	82211	2509	E-GRANULOMATOUS PNEUMONIA;MENINGIOMA
4.1	0.83	0.64	0.50	.20		44.	78	160	220·	220	77067	1849	D-LEIOMYOMA,BLADDER;PULMONARY INJURY
4.4	0.83	0.58	0.44		0.19	41.	71		180+	130	73009	330	D-ADENOCARCINOMA,MAMMARY GLAND
4.8	0.83	0.58	0.46	.17	0.00090	41.	72	140	190	190	78269	1694	E-NEPHROSCLEROSIS;CARCINOMA,PANCREAS
5.9	0.77	0.57	0.44	.15	0.12	40.	70	130	170+	140	73106	419	D-CONGESTIVE HEART FAILURE
5.5	0.77	0.62	0.49	.19	0.17	42.	75	150	200+	150	73058	383	D-CONGESTIVE HEART FAILURE
6.3	0.71	0.55	0.44		0.066	37.	67		180+	120	74355	320	D-PULMONARY INJURY; HYPOTHYROID
5.2	0.71	0.50	0.36	.12	0.0027	35.	61	120	160	160	77322	1383	D-PULMONARY THROMBOSIS
3.6	0.65	0.49	0.38	.15	0.0038	34.	59	120	150	150	75295	1338	D-CONGESTIVE HEART FAILURE
3.7	0.53	0.38	0.29	.11	0.038	27.	47	92	120+	110	73356	669	D-PULMONARY INJURY
2.3	0.50	0.37	0.28	.11		25.	45	88	120	120	77256	2038	E-CHRONIC PYELONEPHRITIS
3.7	0.48	0.38	0.30	.11		26.	46	93	120	120	80036	1607	E-MALIGNANT MELANOMA, MOUTH
3.3	0.47	0.35	0.26	.079		24.	43	86	110	110	79016	1223	E-LYMPHOMA,VISCERAL
3.3	0.49	0.37	0.29	.11	0.00060	25.	45	90	120	120	78265	1691	E-SEMINOMA;BRONCHIOLOALVEOLAR CARCINOMA
4.1	0.46	0.36	0.28	.11		25.	44	89	110	110	81225	2159	E-CARDIAC INSUFFICIENCY
3.5	0.46	0.34	0.27	.10	0.012	23.	42	83	110	110	74218	904	D-ADENOCARCINOMA,MAMMARY GLAND
2.4	0.44	0.34	0.27	.11	0.0018	23.	41	85	120	120	76079	1499	E-ADENOMA,ADRENAL;BRONCHIOLOALV. CARC.
2.9	0.38	0.27	0.21	.081	0.00008	19.	33	67	87	87	77281	2067	E-NEPHRITIS;CONGESTIVE HEART FAILURE
2.2	0.34	0.26	0.21	.078		18.	32	64	84	84	82286	2584	E-SWEAT GLAND ADENOCARCINOMA
2.0	0.33	0.25	0.20	.076	0.00003	17.	30	61	80	80	78236	2375	E-SQUAM. CELL CARC.,ORAL;B-A-CARCINOMA
1.1	0.14	0.11	0.087	.033		7.5	13	26	36	36	79110	1318	E-DISC PROTRUSION
											74342	1034	D-BILATERAL ADRENAL HYPERPLASIA
											77363	2151	D-PYELONEPHRITIS
											74151	843	D-PYOMETRA
											75114	1171	D-ADENOCARCINOMA,MAMMARY GLAND
											77195	1983	E-FIBROBLASTIC OSTEOSARCOMA,BONE
											73265	592	D-ADENOCARCINOMA,MAMMARY GLAND
											77033	1091	D-BRONCHIOLOALVEOLAR CARCINOMA
											79358	1571	D-RENAL FIBROSIS
											82043	2352	E-DISC PROLAPSE;CARCINOMA,LUNG
											83052	2726	E-CONGESTIVE HEART FAILURE
											79302	1515	D-PLEURITIS (NOCARDIA SP.)
											76275	392	D-LOBAR PNEUMONIA

ON EXPOSURE.

LY. PROMINENT FINDINGS ARE INCLUDED.

A.15 ^{90}Sr in Fused Aluminosilicate Particles, Longevity Study

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					DOSE	
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS
417A	04-828	M	H	70288	379	10.6	9.3	100.	001	96.	1014.	3.6	38.	5.0	4.5
415T	01-828	F	I	70288	396	9.2	4.4	41.	002	90.	832.	3.3	31.	4.8	3.9
435A	01-856	M	J	71032	391	11.5	5.2	63.	003	77.	885.	2.8	33.	4.1	3.3
393A	01-792	M	C	70218	427	10.3	3.7	37.	004	74.	763.	2.7	28.	3.9	3.3
416B	02-828	M	H	70288	332	11.6	7.8	89.	005	74.	855.	2.7	32.	3.9	3.5
403A	03-809	M	E	70238	396	7.0	5.2	36.	006	74.	515.	2.7	19.	3.9	3.1
397T	04-792	F	D	70218	409	8.6	5.5	48.	007	73.	629.	2.7	23.	3.9	3.0
500B	04-964	M	L	71300	369	8.6	5.5	48.	008	71.	608.	2.6	22.	3.7	2.8
417T	03-828	F	I	70288	379	9.5	11.	100.	009	70.	661.	2.6	24.	3.7	2.9
403S	04-809	F	F	70238	396	7.0	5.2	36.	010	68.	468.	2.5	17.	3.6	2.4
403U	01-809	F	F	70238	396	6.8	5.5	37.	011	67.	454.	2.5	17.	3.5	2.8
398U	02-792	F	D	70218	393	6.8	3.5	24.	012	66.	452.	2.4	17.	3.5	2.8
432T	01-855	F	K	71029	413	8.2	7.0	59.	013	65.	530.	2.4	20.	3.4	2.7
433A	02-854	M	J	71028	411	11.0	4.1	48.	014	65.	710.	2.4	26.	3.4	2.7
405X	01-824	F	G	70266	416	8.6	4.8	41.	015	63.	541.	2.3	20.	3.3	2.8
355S	01-703	F	B	70036	424	8.6	5.5	48.	016	62.	536.	2.3	20.	3.3	2.6
355B	02-703	M	A	70036	424	9.4	3.7	35.	017	58.	544.	2.1	20.	3.0	2.5
398A	03-792	M	C	70218	393	11.4	3.0	34.	018	57.	652.	2.1	24.	3.0	2.5
408T	02-824	F	G	70266	408	8.6	3.7	33.	019	55.	473.	2.0	18.	2.9	2.5
361T	03-701	F	B	70034	415	8.4	3.3	28.	020	53.	444.	2.0	16.	2.8	2.4
402D	02-809	M	E	70238	397	6.7	7.0	48.	021	53.	354.	2.0	13.	2.8	2.4
357A	01-702	M	A	70035	421	9.8	5.5	52.	022	53.	515.	2.0	19.	2.8	2.3
418S	03-827	F	I	70286	365	10.0	3.3	33.	023	51.	514.	1.9	19.	2.7	2.4
437D	03-855	M	J	71029	332	8.3	3.7	32.	024	51.	423.	1.9	16.	2.7	2.0
494A	03-964	M	L	71300	404	9.4	3.7	36.	025	50.	474.	1.9	18.	2.7	1.9
411A	01-827	M	H	70286	421	14.2	9.6	130.	026	49.	699.	1.8	26.	2.6	2.4
431U	02-855	F	K	71029	421	7.2	8.9	67.	027	48.	348.	1.8	13.	2.5	2.2
402A	01-808	M	E	70237	396	9.5	2.1	20.	028	42.	402.	1.6	15.	2.2	1.9
400S	04-808	F	F	70237	404	9.1	3.1	28.	029	41.	370.	1.5	14.	2.1	1.7
433S	04-854	F	K	71028	411	9.0	2.3	21.	030	38.	339.	1.4	13.	2.0	1.7
411T	03-824	F	G	70266	400	7.6	2.6	20.	031	37.	284.	1.4	11.	2.0	1.8
497B	02-964	M	L	71300	375	8.8	1.8	16.	032	35.	308.	1.3	11.	1.8	1.4
396T	03-790	F	D	70216	417	8.6	3.0	25.	033	33.	282.	1.2	10.	1.7	1.3
398D	02-790	M	C	70216	390	9.5	1.9	18.	034	32.	305.	1.2	11.	1.7	1.4
751A	03-1581	M	O	74338	429	10.0	1.7	17.	035	31.	309.	1.1	11.	1.6	1.4
354W	02-702	F	B	70035	425	7.5	2.3	17.	036	30.	224.	1.1	8.3	1.6	1.3
355A	04-701	M	A	70034	422	10.6	3.6	37.	037	24.	257.	0.89	9.5	1.3	1.1
433C	01-854	M	J	71028	411	9.8	1.1	10.	038	24.	234.	0.89	8.7	1.3	1.1
748S	01-1580	F	N	74337	446	7.6	1.5	11.	039	23.	171.	0.85	6.3	1.2	1.0
414T	04-827	F	I	70286	397	7.0	2.0	14.	040	21.	150.	0.78	5.5	1.1	0.97
416C	02-827	M	H	70286	380	10.7	1.6	17.	041	21.	223.	0.78	8.3	1.1	0.92
759S	03-1586	F	P	74347	415	10.0	1.7	17.	042	21.	208.	0.78	7.7	1.1	0.91
430S	03-854	F	K	71028	423	7.7	1.1	8.5	043	21.	160.	0.78	5.9	1.1	0.90
399U	03-808	F	F	70237	407	7.2	2.0	14.	044	19.	137.	0.70	5.1	1.0	0.86
401B	02-808	M	E	70237	403	9.0	1.9	17.	045	19.	169.	0.70	6.3	0.98	0.85
398B	01-790	M	C	70216	390	11.2	1.0	12.	046	18.	204.	0.67	7.5	0.96	0.82
404S	01-823	F	G	70265	438	8.6	0.89	7.4	047	17.	150.	0.63	5.5	0.92	0.77
748A	02-1581	M	M	74338	447	8.2	0.93	7.4	048	16.	134.	0.59	5.0	0.86	0.78
354A	01-701	M	A	70034	424	10.4	1.8	19.	049	15.	161.	0.55	6.0	0.81	0.70

BETA RADIATION DOSE TO LUNG

	DOSE RATE (GY/DAY)				CUMULATIVE DOSE (GY)							
IAL.	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	POTENTIAL 5000 DAYS	TO DEATH	DEATH DATE	TO DEATH	COMMENT
	4.5	4.3		4.2	280.	550.		11000. +	870.	71118	195	D-PULMONARY INJURY
	3.9	3.4		3.1	260.	470.		13000. +	790.	71143	220	D-PULMONARY INJURY
	3.3	3.0		2.7	220.	410.		11000. +	720.	71263	231	E-PULMONARY INJURY
	3.3	2.8		2.5	220.	400.		1400. +	500.	71012	159	D-PULMONARY INJURY
	3.5	3.2		3.0	210.	420.		3400. +	620.	71107	184	D-PULMONARY INJURY
	3.1	2.7	2.1	2.1	210.	380.	940.	4700. +	990.	71259	386	D-PULMONARY INJURY
	3.0	2.6		2.3	200.	360.		9600. +	600.	71071	218	D-PULMONARY INJURY
	2.8	2.4		2.1	190.	350.		8900. +	640.	72190	255	D-PULMONARY INJURY
	2.9	2.6		2.4	200.	360.		10000. +	730.	71190	267	E-PULMONARY INJURY
	2.4	2.2		1.8	150.	290.		1700. +	510.	71105	232	D-PULMONARY INJURY
	2.8	2.5		2.2	190.	350.		4700. +	670.	71131	258	D-PULMONARY INJURY
	2.8	2.6		2.0	180.	340.		2500. +	820.	71182	329	D-PULMONARY INJURY
	2.7	2.3		1.9	180.	330.		5800. +	640.	71297	268	D-PULMONARY INJURY
	2.7	2.5		2.3	180.	340.		10000. +	650.	71280	252	E-PULMONARY INJURY
	2.8	3.4		2.1	180.	340.		870. +	610.	71144	243	D-PULMONARY INJURY
	2.6	2.3		1.9	180.	320.		4500. +	780.	71013	342	D-PULMONARY INJURY
	2.5	2.2	1.8	1.8	170.	310.	780.	7800. +	800.	71044	373	D-PULMONARY INJURY
	2.5	2.2		2.1	160.	300.		7800. +	640.	71136	283	D-PULMONARY INJURY
	2.5	2.2		2.0	160.	300.		8300. +	540.	71139	238	D-PULMONARY INJURY
	2.4	2.2		1.9	150.	290.		3000. +	590.	70300	266	D-PULMONARY INJURY
	2.4	2.1		1.7	150.	290.		3700. +	620.	71173	300	D-PULMONARY INJURY
	2.3	2.0		1.6	150.	280.		6900. +	670.	71011	341	D-PULMONARY INJURY
	2.4	2.1		1.7	150.	290.		1200. +	440.	71122	201	D-PULMONARY INJURY
	2.0	1.7	1.2	1.2	140.	250.	600.	1600. +	620.	72040	376	E-PULMONARY INJURY
	1.9	1.4		0.67	140.	240.		750. +	420.	72245	310	D-PULMONARY INJURY
	2.4	2.2		2.0	150.	290.		1800. +	450.	71122	201	D-PULMONARY INJURY
	2.2	1.9		1.7	140.	260.		6900. +	450.	71255	226	D-PULMONARY INJURY
	1.9	1.6		1.3	120.	220.		5400. +	530.	71212	340	D-PULMONARY INJURY
	1.7	1.5		1.3	110.	210.		3700. +	430.	71158	286	D-PULMONARY INJURY
	1.7	1.5		1.3	110.	200.		3500. +	420.	71307	279	D-PULMONARY INJURY
	1.8	1.6		1.2	110.	210.		1000. +	400.	71160	259	D-PULMONARY INJURY
	1.4	1.2	0.76	0.51	96.	170.	390.	1200. +	660.	73357	788	D-HEMANGIOSARCOMA,LUNG
	1.3	1.2	0.81	0.52	90.	160.	400.	1000. +	630.	72204	718	D-HEMANGIOSARCOMA,LUNG
	1.4	1.2	0.89	0.70	93.	170.	420.	1500. +	650.	72130	644	E-HEMANGIOSARCOMA,LUNG
	1.4	1.2	0.93	0.67	89.	170.	420.	1500. +	720.	76355	747	E-HEMANGIOSARCOMA,LUNG
	1.3	1.1	0.86	0.80	85.	160.	400.	1700. +	490.	71147	477	D-PULMONARY INJURY
	1.1	0.98	0.65	0.44	71.	130.	330.	1000. +	520.	72019	715	D-HEMANGIOSARCOMA,LUNG
	1.1	1.0	0.78	0.58	71.	140.	350.	1200. +	570.	72356	693	E-HEMANGIOSARCOMA,LUNG
	1.0	0.91	0.69	0.44	65.	120.	310.	1000. +	580.	77084	843	E-HEMANGIOSARCOMA,LUNG
	0.97	0.86	0.60	0.38	63.	120.	290.	1000. +	540.	73064	874	D-HEMANGIOSARCOMA,LUNG
	0.92	0.79	0.50	0.24	60.	110.	260.	840. +	530.	73318	1128	E-EPIDERMOID CARC.;HEMANGIOSARC.,LUNG
	0.91	0.78	0.54	0.37	60.	110.	270.	1100. +	500.	77133	882	E-HEMANGIOSARCOMA,LUNG
	0.90	0.79	0.59	0.41	59.	110.	270.	970. +	490.	73106	809	E-HEMANGIOSARCOMA,LUNG
	0.86	0.74	0.50	0.27	56.	100.	250.	930. +	540.	73311	1170	E-HEMANGIOSARCOMA,LUNG
3	0.85	0.78	0.60	0.30	55.	100.	270.	850. +	560.	73166	1025	D-HEMANGIOSARCOMA,LUNG
5	0.82	0.73	0.54	0.29	53.	99.	250.	820. +	520.	73152	1032	E-HEMANGIOSARC. AND B.A.CARC.,LUNG
2	0.77	0.66	0.45	0.087	50.	93.	230.	660. +	580.	76042	1968	D-HEMANGIOSARCOMA,HEART
5	0.78	0.71	0.50	0.15	49.	94.	240.	870. +	660.	80078	1931	D-PULMONARY INJURY
1	0.70	0.61	0.40	0.18	45.	84.	200.	660. +	430.	73152	1214	E-HEMANG.,LUNG;SQUAM-CELL CARC,LUNG

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A.15 ^{90}Sr in Fused Aluminosilicate Particles, Longevity Study (continued)

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					DOSE RATE (GY/D.			
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	60 DAYS	120 DAYS	(
495C	01-964	M	L	71300	385	8.0	0.89	7.0	050	15.	119.	0.55	4.4	0.78	0.65	0.55	0
362T	02-701	F	B	70034	413	6.8	1.3	8.9	051	15.	101.	0.55	3.7	0.78	0.68	0.60	0.
397S	04-790	F	D	70216	407	8.3	0.96	8.1	052	15.	121.	0.55	4.5	0.76	0.65	0.56	0.
413B	02-826	M	H	70285	409	10.9	0.85	9.3	053	14.	148.	0.52	5.5	0.71	0.60	0.51	0
415V	01-826	F	I	70285	393	7.5	0.85	6.7	054	13.	99.	0.48	3.7	0.70	0.59	0.51	0
405A	02-806	M	E	70236	387	9.7	0.78	7.8	055	9.4	92.	0.35	3.4	0.50	0.41	0.34	0.
438A	04-853	M	J	71027	376	9.9	0.74	7.4	056	9.2	91.	0.34	3.4	0.48	0.39	0.33	0.
358T	01-704	F	B	70037	422	9.0	0.89	7.8	057	9.1	82.	0.34	3.0	0.48	0.44	0.41	0
411S	03-823	F	G	70265	400	8.1	0.85	7.0	058	8.6	70.	0.32	2.6	0.45	0.41	0.38	0
413C	03-826	M	H	70285	409	12.2	0.44	5.2	059	8.5	103.	0.31	3.8	0.45	0.38	0.34	0.
393C	02-789	M	C	70215	424	8.2	0.41	3.4	060	7.9	65.	0.29	2.4	0.42	0.37	0.33	0.
393T	03-789	F	D	70215	424	6.6	0.55	3.2	061	7.9	52.	0.29	1.9	0.42	0.34	0.30	0
399T	01-806	F	F	70236	406	8.0	0.48	4.1	062	7.7	61.	0.28	2.3	0.40	0.36	0.32	0.
367B	04-700	M	A	70033	385	9.6	1.0	8.5	063	7.6	73.	0.28	2.7	0.40	0.36	0.33	0.
754T	02-1580	F	N	74337	410	7.0	0.41	2.7	064	7.4	52.	0.27	1.9	0.39	0.34	0.30	0.
494D	01-963	M	L	71299	403	8.0	0.44	3.6	065	6.8	55.	0.25	2.0	0.36	0.33	0.31	0.
430V	02-853	F	K	71027	422	7.2	0.81	5.9	066	6.6	48.	0.24	1.8	0.35	0.31	0.28	0.
413S	04-326	F	I	70285	409	10.4	0.59	6.3	067	6.6	69.	0.24	2.6	0.35	0.29	0.26	0.
405S	02-323	F	G	70265	416	9.9	0.52	5.2	068	5.7	57.	0.21	2.1	0.30	0.27	0.25	0.
759C	01-1586	M	Q	74347	415	10.9	0.36	4.1	069	5.7	62.	0.21	2.3	0.30	0.26	0.23	0.
352B	02-704	M	A	70037	433	7.9	0.31	2.5	070	5.4	43.	0.20	1.6	0.28	0.25	0.23	0.
755A	01-1581	M	O	74338	409	7.1	0.25	1.8	071	5.3	38.	0.20	1.4	0.28	0.24	0.20	0.
754B	03-1580	M	M	74337	410	8.1	0.34	2.7	072	5.2	42.	0.19	1.6	0.27	0.25	0.22	0.
431T	01-853	F	K	71027	419	6.6	0.37	2.4	073	4.9	33.	0.18	1.2	0.26	0.22	0.21	0.
494B	02-963	M	L	71299	403	9.4	0.41	3.7	074	4.9	46.	0.18	1.7	0.26	0.21	0.18	0.
360T	02-700	F	B	70033	414	7.9	0.93	7.4	075	4.5	35.	0.17	1.3	0.23	0.19	0.16	0.
399S	04-806	F	F	70236	406	9.7	0.31	3.1	076	4.3	41.	0.16	1.5	0.22	0.20	0.18	0.
398S	04-789	F	D	70215	390	9.6	0.36	3.4	077	4.2	40.	0.16	1.5	0.22	0.19	0.17	0.
435C	03-853	M	J	71027	386	9.0	0.25	2.3	078	4.1	37.	0.15	1.4	0.21	0.18	0.16	0.
393D	01-789	M	C	70215	424	10.5	0.27	2.9	079	4.1	43.	0.15	1.6	0.21	0.19	0.17	0.
403B	03-806	M	E	70236	394	7.3	0.26	1.9	080	3.9	28.	0.14	1.0	0.20	0.18	0.17	0.
758U	04-1586	F	P	74347	417	7.0	0.48	3.3	081	3.5	24.	0.13	0.89	0.18	0.15	0.14	0.
755U	02-1586	F	R	74347	418	6.2	0.48	3.1	082	2.6	16.	0.096	0.59	0.14	0.12	0.11	0.
762B	01-1583	M	Q	74344	407	6.7	0.14	0.93	083	1.6	11.	0.059	0.41	0.085	0.074	0.066	0.
756C	02-1584	M	Q	74345	416	11.0	0.085	0.96	084	1.5	17.	0.056	0.63	0.081	0.073	0.067	0.
751U	03-1583	F	P	74344	435	10.2	0.089	0.89	085	1.5	16.	0.056	0.59	0.080	0.068	0.059	0.
749S	02-1577	F	N	74330	430	8.2	0.093	0.74	086	1.5	12.	0.056	0.44	0.079	0.071	0.065	0.
749B	03-1579	M	M	74336	436	8.8	0.093	0.81	087	1.5	13.	0.056	0.48	0.076	0.064	0.057	0.
762U	01-1584	F	R	74345	408	6.9	0.11	0.81	088	1.2	8.5	0.044	0.31	0.065	0.058	0.053	0.
756B	04-1578	M	O	74331	402	10.6	0.085	0.93	089	1.0	11.	0.037	0.41	0.054	0.048	0.044	0.
748B	02-1579	M	O	74336	445	8.7	0.074	0.63	090	0.98	8.5	0.036	0.31	0.051	0.047	0.046	0.
755S	04-1584	F	R	74345	416	10.0	0.10	1.0	091	0.90	9.0	0.033	0.33	0.047	0.044	0.041	0.
754S	04-1585	F	P	74346	419	8.3	0.15	1.2	092	0.80	6.6	0.030	0.24	0.042	0.038	0.035	0.
752A	03-1578	M	M	74331	414	6.7	0.056	0.37	093	0.80	5.3	0.030	0.20	0.042	0.039	0.036	0.
751T	03-1577	F	N	74330	421	9.3	0.085	0.78	094	0.62	5.8	0.023	0.21	0.033	0.029	0.026	0.
754A	01-1579	M	M	74336	409	9.7	0.024	0.23	095	0.32	3.1	0.012	0.11	0.017	0.016	0.015	0.
751V	04-1583	F	R	74344	435	8.4	0.031	0.26	096	0.31	2.6	0.011	0.096	0.016	0.015	0.013	0.
759D	01-1585	M	Q	74346	414	9.1	0.033	0.30	097	0.29	2.7	0.011	0.10	0.015	0.014	0.013	0.
762V	03-1584	F	R	74345	408	6.3	0.067	0.41	098	0.27	1.7	0.010	0.063	0.014	0.013	0.011	0.

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BETA RADIATION DOSE TO LUNG

RATE (GY/DAY) 120 DAYS	365 DAYS	AT DEATH	CUMULATIVE DOSE (GY) 60 DAYS	120 DAYS	365 DAYS	POTENTIAL 5000 DAYS	TO DEATH	DEATH DATE	TO DEATH	COMMENT
0.55	0.36	0.11	43.	78.	190.	600. +	480.	76295	1821	E-HEMANGIOSARC.,SPLEEN; B.A.CARCINOMA
0.60	0.41	0.18	44.	82.	200.	600. +	430.	73123	1185	D-HEMANGIOSARCOMA,LUNG
0.56	0.38	0.064	42.	78.	190.	600. +	540.	77032	2373	D-PULMONARY INJURY
0.51	0.30	0.15	39.	72.	170.	630. +	340.	74037	1213	D-HEMANGIOSARCOMA,LUNG
0.51	0.33	0.11	39.	72.	170.	500. +	380.	74285	1461	D-HEMANGIOSARCOMA,HEART
0.34	0.20	0.035	27.	50.	110.	330. +	290.	76358	2313	E-HEMANGIOSARCOMA,HEART
0.33	0.23	0.035	26.	47.	110.	400. +	360.	78223	2753	E-HEMANGIOSARC.,RIB;B-A-CARCINOMA
0.41	0.32	0.049	28.	53.	140.	490. +	440.	76275	2429	D-HEMANGIOSARCOMA,HEART;B-A-CARCINOMA
0.38	0.27	0.016	26.	50.	130.	340. +	320.	77304	2596	D-PULMONARY INJURY;COMBINED CARC.,LUNG
0.34	0.23	0.029	25.	46.	110.	340. +	310.	77224	2496	E-SQUAMOUS CELL CARCINOMA,NASAL CAVITY
0.33	0.24	0.083	24.	45.	110.	410. +	310.	75072	1683	E-HEMANGIOSARCOMA,SITE UNDETERMINED
0.30	0.19	0.010	23.	42.	100.	290. +	280.	79234	3306	D-HEMANGIOSARCOMA,HEART
0.32	0.23	0.077	23.	43.	110.	400. +	310.	75217	1807	D-HEMANGIOSARCOMA,TBLN
0.33	0.23	0.030	23.	43.	110.	340. +	310.	77091	2615	D-ASPIRATION PNEUMONIA;B-A-CARCINOMA
0.30	0.22	0.093	22.	41.	100.	410. +	290.	79104	1593	D-HEMANGIOSARCOMA,HEART
0.31	0.25	0.083	21.	40.	110.	400. +	310.	76176	1703	D-HEMANGIOSARCOMA,HEART
0.28	0.20	0.043	20.	37.	95.	340. +	290.	77140	2305	E-HEMANGIOSARCOMA,HEART
0.26	0.18	0.027	19.	36.	87.	280. +	250.	77177	2449	D-HEMANGIOSARCOMA,HEART
0.25	0.17	0.0063	17.	33.	84.	220. +	210.	81014	3767	E-HEMANGIOSARCOMA,DISSEMINATED
0.23	0.16	0.043	17.	32.	80.	290. +	230.	80260	2104	E-HEMANGIOSARCOMA,LUNG
0.23	0.17	0.023	16.	3.0	79.	290. +	260.	77310	2830	D-SQ.CELL CARC,LUNG;HEMANGIOSARC.,TBLN
0.20	0.14	0.022	16.	29.	72.	230. +	220.	84163	3477	D-HEMANGIOSARCOMA,UNDET.;PUL. ADENOMA
0.22	0.17	0.059	15.	30.	78.	320. +	240.	80109	1963	E-HEMANGIOSARCOMA,MUSCLE
0.21	0.17	0.047	14.	27.	74.	300. +	240.	76295	2094	D-HEMANGIOSARCOMA,HEART
0.18	0.12	0.020	14.	25.	60.	200. +	180.	78329	2587	D-HEMANGIOSARCOMA,TBLN
0.16	0.10	0.0040	13.	23.	53.	150. +	140.	79158	3412	D-ULCERATIVE PHARYNGITIS
0.18	0.13	0.035	13.	24.	62.	230. +	190.	76201	2156	D-HEMANGIOSARCOMA,HEART
0.17	0.12	0.020	12.	23.	57.	200. +	170.	77223	2565	E-HEMANGIOSARCOMA,LUNG
0.16	0.12	0.038	12.	22.	55.	240. +	190.	77076	2241	E-HEMANGIOSARCOMA,HEART
0.17	0.12	0.013	12.	23.	57.	200. +	190.	79173	3245	E-HEMANGIOSARCOMA,HEART
0.17	0.12	0.020	12.	22.	56.	200. +	180.	77315	2636	E-HEMANGIOSARC.,SITE UND.;B-A-CARCINOMA
0.14	0.11	0.029	10.	19.	48.	180. +	150.	80186	2030	E-HEMANGIOSARCOMA,SPLEEN
0.11	0.079	0.019	7.7	15.	37.	130. +	110.	81091	2301	E-HEMANGIOSARCOMA, LIVER
0.066	0.049	0.0070	4.8	9.0	23.	88. +	86.	86161	4200	E-HEMANGIOSARCOMA,TBLN
0.067	0.048	0.0090	4.6	8.8	23.	84. +	80.	85256	3929	E-HEMANGIOSARCOMA,TBLN
0.059	0.040	0.0070	4.4	8.2	20.	70. +	61.	84024	3332	E-ANGIOSARCOMA,TBLN
0.065	0.050	0.010	4.5	8.5	22.	90. +	85.	84272	3594	E-HEMANGIOSARCOMA,HEART
0.057	0.042	0.0060	4.2	7.8	20.	73. +	72.	89153	5296	D-PUL. FIBROSIS, PUL. ADENOCARCINOMA
0.053	0.039	0.0050	3.7	7.0	18.	66. +	64.	86234	4274	E-HEMANGIOSARCOMA,TBLN;CARCINOMA,LUNG
0.044	0.031	0.0077	3.1	5.8	15.	48. +	39.	80045	1905	E-HEMANGIOSARCOMA,TBLN
0.046	0.036	0.0040	3.0	5.8	16.	71. +	73.	88047	4824	E-MESOTHELIOMA, PLEURAL
0.041	0.032	0.0040	2.7	5.3	14.	55. +	49.	83213	3155	E-HEMANGIOSARCOMA,SPLEEN
0.035	0.028	0.0040	2.4	4.6	12.	45. +	44.	84314	3620	E-CARCINOMA,LUNG
0.036	0.028	0.0050	2.4	4.7	12.	52. +	48.	85345	4032	E-HEMANGIOSARCOMA,TBLN
0.026	0.019	0.0048	1.8	3.5	8.8	31. +	26.	80193	2057	E-HEMANGIOSARCOMA,TBLN
0.015	0.012	0.0012	0.99	1.9	5.2	23. +	22.	86365	4412	D-CARDIOMYOPATHY,HEART
0.013	0.0093	0.00080	0.93	1.8	4.5	17. +	16.	86199	4238	E-CARCINOMA,MAMMARY GLAND
0.013	0.010	0.0010	0.89	1.7	4.6	17. +	16.	86323	4774	E-CHOLANGIOCARCINOMA,LIVER
0.011	0.0069	0.00070	0.81	1.5	3.7	10. +	8.8	82188	2765	E-HEMANGIOSARCOMA,TBLN

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A.15 ^{90}Sr in Fused Aluminosilicate Particles, Longevity Study (continued)

DOG IDENTIFICATION			INHALATION EXPOSURE				I.B.B.		I.L.B.					DC	
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	MBQ/KG	MBQ	RANK	UCI/KG	UCI	MBQ/KG	MBQ	INITIAL	6C DAY
758T	03-1585	F	P	74346	416	7.0	0.017	0.12	099	0.26	1.8	0.0096	0.067	0.014	0.01
748T	04-1579	F	N	74336	445	5.8	0.026	0.15	100	0.25	1.5	0.0093	0.056	0.013	0.01
763A	02-1585	M	Q	74346	408	9.9	0.024	0.24	101	0.22	2.2	0.0081	0.081	0.011	0.01
750A	01-1577	M	M	74330	428	10.5	0.022	0.23	102	0.18	1.8	0.0067	0.067	0.0092	0.00
763S	02-1583	F	P	74344	406	8.2	0.033	0.27	103	0.15	1.2	0.0056	0.044	0.0078	0.00
758C	01-1578	M	O	74331	401	7.7	0.021	0.17	104	0.15	1.1	0.0056	0.041	0.0077	0.00
756A	02-1578	M	O	74331	402	10.2	0.024	0.24	105	0.12	1.3	0.0044	0.048	0.0065	0.00
749T	04-1577	F	N	74330	430	7.9	0.027	0.21	106	0.12	0.94	0.0044	0.035	0.0062	0.0[illegible]
354S	02-699	F	B	70027	417	7.8			C						
361B	01-699	M	A	70027	408	12.0			C						
397U	01-788	F	D	70212	403	7.5			C						
399B	02-788	M	C	70212	382	10.9			C						
401S	01-811	F	F	70240	406	8.5			C						
402B	02-811	M	E	70240	399	11.1			C						
405W	01-816	F	G	70247	398	6.8			C						
413U	01-830	F	I	70289	413	9.4			C						
418C	02-830	M	H	70289	368	11.4			C						
431S	02-851	F	K	71025	417	7.4			C						
437A	01-851	M	J	71025	378	10.9			C						
497A	01-962	M	L	71299	374	11.1			C						
751S	03-1576	F	N	74329	420	11.6			C						
754C	01-1576	M	M	74329	402	6.7			C						
758A	02-1576	M	O	74329	399	11.2			C						
758B	03-1582	M	Q	74343	413	10.4			C						
761S	01-1582	F	R	74343	407	9.8			C						
762T	02-1582	F	P	74343	406	7.2			C						

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDINGS AR

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BETA RADIATION DOSE TO LUNG

	DOSE RATE (GY/DAY)				CUMULATIVE DOSE (GY)							
IAL	60 DAYS	120 DAYS	365 DAYS	AT DEATH	60 DAYS	120 DAYS	365 DAYS	POTENTIAL 5000 DAYS	TO DEATH	DEATH DATE	TO DEATH	COMMENT
14	0.013	0.012	0.0087	0.00060	0.79	1.5	4.0	11. +	10.	82351	2927	D-PULMONARY THROMBOSIS
13	0.012	0.011	0.0079	0.00030	0.76	1.5	3.8	9.7+	9.5	86143	4190	D-HEART FAILURE
11	0.011	0.0099	0.0075	0.00080	0.66	1.3	3.4	15. +	14.	88041	4808	E-HEMANGIOSARCOMA, SPLEEN
92	0.0085	0.0079	0.0058	0.00080	0.53	1.0	2.7	11. +	9.5	85172	3860	E-LYMPHOSARCOMA,LIVER
78	0.0072	0.0067	0.0048	0.00020	0.45	0.87	2.3	5.8+	5.7	87182	4591	E-LYMPHOSARCOMA,BRAIN
77	0.0072	0.0068	0.0054	0.00070	0.45	0.87	2.4	7.9+	7.7	84093	3414	E-HEMANGIOSARCOMA,TBLN
65	0.0060	0.0056	0.0040	0.00020	0.38	0.72	1.9	6.6+	6.2	88176	4958	E-PYELONEPHRITIS
62	0.0059	0.0055	0.0042	0.00045	0.36	0.70	1.9	5.7+	5.5	82075	2667	E-HEMANGIOSARCOMA,LIVER
										81198	4189	E-ADENOCARCINOMA, MAMMARY GLAND
										83211	4932	D-CARCINOMA,LUNG
										85273	5540	E-PYELONEPHRITIS,KIDNEY
										84073	4974	E-ADENOCARCINOMA,PROSTATE
										85106	5345	E-ADENOCARCINOMA,MAMMARY GLAND
										85133	5372	D-BRONCHOPNEUMONIA,LUNG
										80275	3680	D-CARCINOMA,LUNG
										83244	4703	E-CARCINOMA,BLADDER
										85067	5257	E-MALIGNANT MELONOMA,ORAL
										82244	4237	E-TRANSITIONAL CELL CARCINOMA,BLADDER
										85318	5407	D-LYMPHOSARCOMA,GENERALIZED
										82140	3859	E-CARCINOMA,HEPATOCELLULAR
										86200	4254	D-FIBROMA,VAGINA
										86022	4076	D-HEMANGIOSARCOMA,HEART
										84211	3534	E-ADENOCARCINOMA,PANCREAS
										86325	4375	D-BRONCHIOLITIS,LUNG
										81344	2558	D-ACCIDENTAL DEATH
										91159	6025	D-PYELONEPHRITIS;CARCINOMA,LUNG

INGS ARE INCLUDED.

2

A.16 ^{144}Ce in Fused Aluminosilicate Particles, Repeated Exposure Study

DOG IDENTIFICATION				INITIAL EXPOSURE			FINAL EXPOSURE			BETA RADIATION DOSE TO LUNG					
										DOSE RATE (GY/DAY)			CUMULATIVE DC		
TATTOO	AN-EXPT	SEX	GROUP	DATE	AGE DAYS	WT KG	DATE	AGE DAYS	WT KG	AFTER INITIAL EXP.	AFTER FINAL EXP.	AT DEATH	365 DAYS	730 DAYS	POTE INFI
645C	01-1294	M	I	73340	518	8.3	75288	1195	9.5	.18	.75	.0028	130	370	52
648U	02-1294	F	I	73340	513	6.5	75288	1191	7.1	.18	.64		130	350	48
664C	03-1294	M	I	73340	452	9.6	75288	1130	11.7	.20	.65	.0038	130	370	50
641T	04-1294	F	I	73340	526	8.9	75288	1204	11.5	.19	.60	.0017	110	310	44
644T	05-1294	F	I	73340	518	7.1	75288	1195	8.3	.14	.64	.065	120	350	48
646S	01-1295	F	I	73341	518	7.1	75289	1196	9.0	.15	.48		100	260	36
654T	02-1295	F	I	73341	495	7.6	75289	1173	8.5	.17	.72	.0011	130	350	50
645S	03-1295	F	I	73341	519	9.0	75289	1197	12.5	.24	.55	.00044	110	[illegible]	4[illegible]
641C	04-1295	M	I	73341	527	9.3	75289	1205	11.3	.23	.71	.0012	150	380	52
662U	01-1292	F	II	73338	458	6.2	75286	1136	7.2	.58	.46		170	340	43
654B	02-1292	M	II	73338	492	6.3	75286	1170	7.2	.54	.54		160	340	45
645A	03-1292	M	II	73338	516	10.7	75286	1194	12.1	.74	.55	.00085	180	360	47
651S	04-1292	F	II	73338	500	8.4	75286	1178	9.4	.62	.57		170	360	47
665B	05-1292	M	II	73338	434	8.8	75286	1112	10.2	.67	.53	.00052	180	350	46
654A	01-1293	M	II	73339	493	10.6	75287	1171	11.6	.56	.53	.0022	180	380	49
641B	02-1293	M	II	73339	525	10.9	75287	1203	12.5	.55	.46	.00056	170	340	43
648B	03-1293	M	II	73339	512	8.6	75287	1220	9.0	.55	.58	.0054	170	370	48
648S	04-1293	F	II	73339	512	7.5	75287	1220	8.2	.66	.65	.020	190	390	52
649U	01-1290	F	III	73333	502	9.2	75282	1180	9.2	.30	.28	.0036	87	180	23
650U	02-1290	F	III	73333	501	8.5	75282	1178	10.0	.26	.32		91	200	26
649V	03-1290	F	III	73333	502	7.8	75282	1180	8.9	.33	.29	.00056	93	190	25
650B	04-1290	M	III	73333	501	9.8	75282	1178	11.3	.30	.34		93	200	27
641A	05-1290	M	III	73333	519	13.5	75282	1178	13.2	.34	.24	.00072	87	180	23
662S	01-1291	F	III	73334	454	10.8	75283	1133	11.5	.31	.19	.00019	85	210	25
655U	02-1291	F	III	73334	486	8.2	75283	1165	10.4	.28	.25	.0028	78	160	21
644S	03-1291	F	III	73334	512	10.5	75283	1191	11.6	.33	.23		84	170	21
665A	04-1291	M	III	73334	430	10.4	75283	1109	10.9	.39	.25	.17	94	190	24
664B	01-1288	M	C	73331	443	11.3	75273	1115	11.8						
664A	02-1288	M	C	73331	443	11.9	75273	1115	11.9						
648T	03-1288	F	C	73331	504	7.9	75273	1076	8.9						
663S	04-1288	F	C	73331	451	9.5	75273	1123	11.2						
646B	05-1288	M	C	73331	508	8.2	75050	957	9.8						
648A	01-1289	M	C	73332	505	8.4	75274	1178	9.1						
649B	02-1289	M	C	73332	501	10.9	75274	1174	11.4						
662T	03-1289	F	C	73332	452	9.8	75274	1124	9.7						
657A	04-1289	M	C	73332	477	9.6	75274	1150	10.6						

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EXPOSURE GROUPS:
- GROUP I - LUNG BURDEN INCREASED BY .093 MBQ (2.5 UCI) 144-CE/KG BODY WEIGHT EVERY 56 DAYS FOR 13 EXPOSU
- GROUP II - LUNG BURDEN RE-ESTABLISHED AT .33 MBQ (9.0 UCI) 144-CE/KG BODY WEIGHT EVERY 56 DAYS FOR 13 EX
- GROUP III - LUNG BURDEN RE-ESTABLISHED AT .17 MBQ (4.5 UCI) 144-CE/KG BODY WEIGHT EVERY 56 DAYS FOR 13 EX

UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
MBQ/KG REPRESENTS MEGABEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
+ INDICATES THE DOG DIED BEFORE IT RECEIVED ITS POTENTIAL INFINITE DOSE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINENT FINDING

. RADIATION DOSE TO LUNG

DAY)	CUMULATIVE DOSE (GY)						
AT DEATH	365 DAYS	730 DAYS	POTENT. INFIN.	TO DEATH	DEATH DATE	DAYS FROM FIRST INHALATION TO DEATH	COMMENT
.0028	130	370	520	520	79240	2091	D-MYELOMALACIA;HEMANGIOSARCOMA,LUNG
	130	350	480	480	80275	2491	D-FIBRINOUS PNEUMONIA
.0038	130	370	500	500	79124	1975	D-HEMANGIOSARC.,SPLEEN;SQUAM.CELL CARC.,LUNG
.0017	110	310	440	440	79315	2166	D-PULMONARY INJURY
.065	120	350	480+	460	77135	1256	D-PULMONARY INJURY
	100	260	360	360	85117	4159	D-INTERSTITIAL PNEUMONIA
.0011	130	350	500	500	80094	2309	D-HEMANGIOSARCOMA,HEART
.00044	110	300	410	410	80263	2478	E-CARCINOMA,THYROID
.0012	150	380	520	520	80074	2289	D-CARCINOMA,LUNG
	170	340	430	430	81254	2838	E-HEMANGIOSARCOMA,TBLN;CARCINOMA,LUNG
	160	340	450	450	83019	3333	E-HEMANGIOSARCOMA,SPLEEN
.00085	180	360	470	470	80092	2310	D-CARCINOMA,LUNG
	170	360	470	470	82292	3241	E-CARCINOMA,LUNG;HEMANGIOSARCOMA,TBLN
.00052	180	350	460	460	80211	2429	D-ADENOCARCINOMA,LUNG
.0022	180	380	490	490	79215	2067	C-PNEUMONITIS AND FIBROSIS;B-A-CARCINOMA
.00056	170	340	430	430	80151	2368	D-CARCINOMA,LUNG
.0054	170	370	480	480	79008	1860	D-PNEUM. AND FIBROSIS;B-A-CARC.;HEMANGIOSARC.,TBLN
.020	190	390	520	520	78071	1558	D-HEMOLYTIC ANEMIA
.0036	87	180	230	230	78279	1772	E-PARVOVIRUS INFECTION
	91	200	260	260	81202	2791	E-HEMANGIOSARCOMA,SPLEEN
.00056	93	190	250	250	80032	2255	E-TUMOR,BRAIN
	93	200	270	270	84200	3884	E-COMBINED CARCINOMA,LUNG;CARCINOSARCOMA,LUNG
.00072	87	180	230	230	79292	2150	E-HEMANGIOSARCOMA,LIVER
.00019	85	210	250	250	80199	2421	D-HEMANGIOSARCOMA,TBLN
.0028	78	160	210	210	78312	1804	E-HEMANGIOSARCOMA,TBLN
	84	170	210	210	83139	3457	D-RADIATION PNEUMONITIS AND PULMONARY FIBROSIS
.17	94	190	240+	190	76010	771	D-BONE MARROW APLASIA
					83356	3677	E-THYROID CARCINOMA
					86004	4421	D-HEMANGIOSARCOMA,KIDNEY
					76288	1052	D-AUTOHEMOLYTIC ANEMIA
					88273	5420	D-CARCINOMA,LUNG
					75067	466	D-ACCIDENTAL DEATH AFTER NINTH EXPOSURE
					88133	5279	E-LYMPHOSARCOMA,LIVER
					83166	3486	D-TRANSITIONAL CELL CARCINOMA,BLADDER
					86209	4625	E-FIBROSARCOMA,ORAL CAVITY
					85249	4300	D-PROSTATITIS

ERY 56 DAYS FOR 13 EXPOSURES.
T EVERY 56 DAYS FOR 13 EXPOSURES.
T EVERY 56 DAYS FOR 13 EXPOSURES.

ATION EXPOSURE.

IVELY. PROMINENT FINDINGS ARE INCLUDED.

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A.17 $^{238}PuO_2$ Monodisperse Aerosol (1.5 μm AMAD), Longevity Study

DOG IDENTIFICATION		INHALATION EXPOSURE					ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RADIATION DOSE TO DEATH (GY)					
					AGE	WT							FROM ILB (WBC)			FROM ILB (REC.)		
TATTOO	AN-EXPT	SEX	BLOCK	DATE	DAYS	KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	LUNG	LIVER	BONE	LUNG	LIVER	BON
701A	02-1444	M	C	74122	430	9.4	01	1.0	9.3	37.	340.	300	59.	20.	9.6	51.	17.	8.3
857V	01-1742	F	J	75343	395	9.8	02	1.0	9.3	37.	340.	440	57.	15.	7.1	74.	19.	9.2
746B	02-1548	M	G	74253	364	10.3	03	0.87	9.3	32.	340.	280	66.	8.9	4.2	52.	7.1	[illegible]
718U	01-1484	F	F	74169	406	7.5	04	0.87	6.1	32.	230.	280	48.	15.	7.4	54.	17.	8.3
726A	02-1490	M	E	74171	378	11.5	05	0.80	9.3	30.	340.	260	62.	13.	6.1	47.	9.6	4.7
690S	02-1358	F	B	74029	400	8.0	06	0.80	6.1	30.	230.	210	46.	16.	7.5	41.	14.	6.8
684A	01-1362	M	A	74031	417	10.5	07	0.55	5.8	20.	210.	190	33.	13.	6.1	28.	11.	5.1
877C	02-1832	M	K	76078	414	13.1	08	0.52	6.7	19.	250.	440	32.	2.6	1.2	55.	4.5	2.1
747S	03-1552	F	H	74255	366	7.8	09	0.49	3.8	18.	140.	130	[illegible]	11.	5.3	27.	10.	4.9
726T	03-1484	F	F	74169	376	10.0	10	0.44	4.3	16.	160.	150	26.	11.	5.3	26.	11.	5.3
746T	01-1552	F	H	74255	366	9.6	11	0.41	3.9	15.	140.	110	24.	8.2	4.0	19.	6.3	3.1
708T	02-1440	F	D	74120	406	7.3	12	0.39	2.8	14.	100.	160	23.	6.0	2.9	35.	9.2	4.4
745A	03-1548	M	G	74253	368	7.9	13	0.37	2.9	14.	110.	110	22.	9.0	4.4	22.	9.0	4.4
707T	03-1444	F	D	74122	412	8.6	14	0.33	2.8	12.	100.	93	20.	8.6	4.2	18.	7.6	3.8
723C	01-1490	M	E	74171	383	8.7	15	0.32	2.8	12.	100.	100	19.	7.5	3.7	22.	8.5	4.2
858B	02-1746	M	I	75345	395	10.6	16	0.30	3.1	11.	110.	140	17.	5.3	2.6	20.	5.9	2.9
737A	02-1552	M	G	74255	418	10.3	17	0.29	3.0	11.	110.	89	18.	7.7	3.7	14.	5.9	2.9
861S	02-1742	F	J	75343	380	8.0	18	0.29	2.3	11.	85.	130	17.	4.8	2.3	25.	6.9	3.3
877T	02-1828	F	L	76077	413	9.8	19	0.27	2.6	10.	96.	200	16.	6.0	3.0	31.	12.	5.8
858T	02-1744	F	J	75344	394	9.5	20	0.27	2.5	10.	93.	24	16.	16.	7.6	4.3	4.3	2.0
705B	01-1444	M	C	74122	416	8.0	21	0.26	2.1	9.6	78.	67	16.	7.8	3.7	14.	6.7	3.2
880T	01-1828	F	L	76076	401	7.6	22	0.25	1.9	9.3	70.	120	15.	5.7	2.8	25.	9.6	4.7
693B	03-1362	M	A	74031	383	9.7	23	0.23	2.3	8.5	85.	85	14.	6.6	3.2	14.	6.6	3.2
862A	01-1746	M	I	75345	380	8.3	24	0.23	1.9	8.5	70.	96	14.	4.9	2.4	18.	6.4	3.1
860C	03-1746	M	I	75345	384	11.0	25	0.21	2.3	7.8	85.	120	13.	5.6	2.7	16.	7.1	3.5
725B	02-1492	M	F	74172	379	11.3	26	0.20	2.2	7.4	81.	96	12.	6.6	3.2	13.	6.9	3.3
699A	01-1440	M	C	74120	434	8.3	27	0.19	1.5	7.0	56.	81	11.	4.7	2.3	15.	6.6	3.2
685A	03-1358	M	A	74029	415	10.0	28	0.19	1.9	7.0	70.	70	12.	5.9	2.9	12.	6.2	3.0
692S	01-1358	F	B	74029	384	8.3	29	0.18	1.5	6.7	56.	52	11.	6.4	3.1	11.	6.0	2.9
691S	03-1360	F	B	74030	399	13.0	30	0.17	1.7	6.3	63.	63	8.1	4.9	2.4	8.6	5.2	2.5
715C	02-1484	M	E	74169	422	9.6	31	0.15	1.4	5.6	52.	100	9.0	5.1	2.4	18.	10.	3.9
725T	02-1486	F	F	74170	377	11.2	32	0.15	1.7	5.6	63.	74	9.3	4.7	2.3	11.	5.5	2.7
876A	03-1828	M	K	76077	421	11.7	33	0.13	1.5	4.8	56.	100	7.7	2.8	1.4	13.	4.6	2.3
704U	03-1440	F	D	74120	415	8.8	34	0.12	1.1	4.4	41.	78	7.5	2.6	1.3	14.	4.8	2.3
875A	03-1832	M	K	76078	427	13.2	35	0.11	1.5	4.1	56.	85	6.9	2.9	1.4	8.7	3.7	1.8
745T	01-1554	F	H	74256	371	9.1	36	0.10	0.87	3.7	32.	44	9.7	8.0	4.0	7.7	6.4	3.2
746A	01-1550	M	G	74254	365	8.7	37	0.090	0.80	3.3	30.	41	5.7	4.2	2.0	7.8	5.9	2.8
875S	01-1832	F	L	76078	427	10.7	38	0.090	1.0	3.3	37.	85	5.7	2.5	1.2	12.	5.3	2.6
692U	02-1362	F	B	74031	386	6.3	39	0.090	0.53	3.3	20.	31	5.3	4.1	2.0	5.3	4.1	2.2
877B	03-1834	M	K	76079	415	11.4	40	0.090	1.0	3.3	37.	59	5.4	2.7	1.3	11.	5.4	2.1
718V	03-1490	F	F	74171	408	7.9	41	0.080	0.63	3.0	23.	41	4.9	3.4	1.6	7.8	6.2	3.1
879S	01-1830	F	L	76077	405	9.7	42	0.070	0.73	2.6	27.	48	4.6	1.8	0.90	8.1	3.2	1.4
685B	03-1364	M	A	74032	418	9.4	43	0.070	0.67	2.6	25.	33	4.5	3.3	1.6	4.9	3.6	1.7
738A	03-1550	M	G	74254	410	10.4	44	0.070	0.73	2.6	27.	31	4.4	2.1	1.3	4.5	3.4	1.6
860B	03-1744	M	I	75344	383	10.7	45	0.060	0.61	2.2	23.	31	3.6	2.7	1.3	5.3	3.9	1.8
708U	02-1446	F	D	74123	409	7.4	46	0.060	0.42	2.2	16.	30	3.6	3.8	1.8	8.0	8.9	4.0
744U	01-1548	F	H	74253	376	7.8	47	0.060	0.44	2.2	16.	23	3.5	1.8	0.90	7.9	4.1	2.0
857X	01-1748	F	J	75346	398	9.3	48	0.060	0.51	2.2	19.	41	3.2	2.4	1.1	7.3	5.7	2.7
874B	03-1830	M	K	76077	428	12.3	49	0.050	0.59	1.9	22.	37	3.0	2.0	1.0	5.0	3.5	1.7

CUMULATIVE ALPHA RADIATION

DOSE TO DEATH (GY)

M ILB (WBC) LIVER	BONE	FROM ILB (REC.) LUNG	LIVER	BONE	DEATH DATE	DAYS TO DEATH	COMMENT
20.	9.6	51.	17.	8.3	78012	1351	E-OSTEOSARCOMA,HUMERUS
15.	7.1	74.	19.	9.2	78344	1097	D-PNEUMONITIS AND PULMONARY FIBROSIS
8.9	4.2	52.	7.1	3.4	76315	792	D-PNEUMONITIS AND PULMONARY FIBROSIS
15.	7.4	54.	17.	8.3	77355	1282	E-OSTEOSARC.,LUMB. VERT.;CARCINOMA,LUNG
13.	6.1	47.	9.6	4.7	77182	1107	E-PNEUM. AND PUL. FIBROS.;CARC.,LUNG(I)
16.	7.5	41.	14.	6.8	77313	1300	E-OSTEOSARCOMA,THOR. AND LUM.VERT.
13.	6.1	28.	11.	5.1	78073	1503	E-OSTEOSARC.,THOR.VERT.;SARC.,LUNG(I)
2.6	1.2	55.	4.5	2.1	77248	536	D-PNEUMONITIS AND PULMONARY FIBROSIS
11.	5.3	27.	10.	4.9	78275	1481	D-CARCINOMA,LUNG
11.	5.3	26.	11.	5.3	79023	1680	E-OSTEOSARC.,THOR.;CARC,LUNG(I)
8.2	4.0	19.	6.3	3.1	78171	1377	E-OSTEOSARCOMA,HUMERUS
6.0	2.9	35.	9.2	4.4	77128	1104	D-IMM.HEM.ANEMIA;PNEUM. AND PUL. FIBROS.
9.0	4.4	22.	9.0	4.4	79045	1618	E-OSTEOSARCOMA,FEMUR AND STERNUM
8.6	4.2	18.	7.6	3.8	79039	1743	E-OSTEOSARCOMA,HUMERUS
7.5	3.7	22.	8.5	4.2	78763	1553	E-OSTEOSARCOMA,ILIUM
5.3	2.6	20.	5.9	2.9	79129	1245	E-OSTEOSARCOMA,SACRUM;CARCINOMA,LUNG(I)
7.7	3.7	14.	5.9	2.9	79178	1749	E-OSTEOSARC.,HUM.,LUM.VERT. AND ISCHIUM
4.8	2.3	25.	6.9	3.3	79047	1165	E-OSTEOSARCOMA,LUMBAR VERTEBRAE
6.0	3.0	31.	12.	5.8	80133	1517	E-BONE TUMOR,T3
16.	7.6	4.3	4.3	2.0	87016	4055	E-SARCOMA, SITE UNDETERMINED
7.8	3.7	14.	6.7	3.2	79255	1959	E-OSTEOSARCOMA, THOR. VERT. AND HUMERUS
5.7	2.8	25.	9.6	4.7	80129	1514	E-BONE TUMOR,T2
6.6	3.2	14.	6.6	3.2	79038	1833	E-OSTEOSARCOMA,HUMERUS
4.9	2.4	18.	6.4	3.1	79306	1472	D-OSTEOSARCOMA,C5,L2
5.6	2.7	16.	7.1	3.5	80304	1785	E-OSTEOSARCOMA,HUMERUS
6.6	3.2	13.	6.9	3.3	80276	2295	E-OSTEOSARCOMA,HUMERUS
4.7	2.3	15.	6.6	3.2	79010	1716	D-OSTEOSARCOMA,SCAPULA
5.9	2.9	12.	6.2	3.0	79281	2078	E-OSTEOSARCOMA,T5;CARCINOMA,LUNG
6.4	3.1	11.	6.0	2.9	80254	2416	E-FIBROSARCOMA,LIVER
4.9	2.4	8.6	5.2	2.5	81019	2546	E-OSTEOSARCOMA,TIBIA
5.1	2.4	18.	10.	3.9	80324	2346	E-OSTEOSARCOMA,HUMERUS AND SKULL
4.7	2.3	11.	5.5	2.7	80028	2049	E-BONE TUMOR,HUMERUS
2.8	1.4	13.	4.6	2.3	80060	1444	E-BONE TUMOR,T12
2.6	1.3	14.	4.8	2.3	78072	1413	E-DISC PROTRUS.;CARCINOMA,LUNG(I)
2.9	1.4	8.7	3.7	1.8	80305	1658	E-OSTEOSARCOMA,VERT. T10
8.0	4.0	7.7	6.4	3.2	84116	3512	E-OSTEOSARCOMA,ILIUM
4.2	2.0	7.8	5.9	2.8	83098	3131	D-MAST CELL TUMOR
2.5	1.2	12.	5.3	2.6	81016	1765	E-OSTEOSARCOMA,ILIUM
4.1	2.0	5.3	4.1	2.2	83087	3343	E-OSTEOSARCOMA,LUMBAR VERT. L7
2.7	1.3	11.	5.4	2.1	81302	2050	E-OSTEOSARCOMA,PELVIS
3.4	1.6	7.8	6.2	3.1	82183	2934	E-OSTEOSARCOMA,SACRUM
1.8	0.90	3.1	3.2	1.4	80204	1588	E-BONE TUMOR,T8
3.3	1.6	4.9	3.6	1.7	82278	3168	E-OSTEOSARC., THOR.T2 AND LUMBAR VERT.L6
2.1	1.3	4.5	3.4	1.6	82098	2766	E-OSTEOSARCOMA,VERTEBRAE,T12,L1
2.7	1.3	5.3	3.9	1.8	84135	3178	E-FIBROSARC.,LIVER;SQUAM. CARC.,GINGIVA
3.8	1.3	6.0	8.9	4.0	86043	4303	E-OSTEOSARCOMA,BONE;CARCINOMA,LUNG
1.8	0.90	7.9	4.1	2.0	80194	2172	F-ULCERATIVE ILEITIS
2.4	1.1	7.3	5.7	2.7	84289	3230	E-OSTEOSARCOMA,PARIETAL;CARCINOMA,LUNG
2.0	1.0	5.0	3.5	1.7	84002	2947	E-OSTEOSARCOMA,HUMERUS

A.17 $^{238}PuO_2$ Monodisperse Aerosol (1.5 μm AMAD), Longevity Study (continued)

DOG IDENTIFICATION			INHALATION EXPOSURE				ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RADIATION DOSE TO DEATH (GY)					
					AGE	WT							FROM ILB (WBC)			FROM ILB (REC.)		
TATTOO	AN-EXPT	SEX	BLOCK	DATE	DAYS	KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	LUNG	LIVER	BONE	LUNG	LIVER	BONE
704T	01-1446	F	D	74123	418	9.5	50	0.050	0.45	1.9	17.	26	2.9	1.8	0.90	3.2	2.0	0.9
705A	01-1442	M	C	74121	415	10.5	51	0.050	0.49	1.9	18.	37	2.9	2.2	1.0	5.3	4.6	2.2
694A	02-1360	M	A	74030	370	11.3	52	0.050	0.53	1.9	20.	41	2.8	2.3	1.1	5.3	5.0	2.2
862T	03-1742	F	J	75343	378	6.8	53	0.040	0.28	1.5	10.		2.3	3.1	1.4			
746S	02-1554	F	H	74256	367	10.9	54	0.040	0.42	1.5	16.	32	2.5	2.1	1.1	4.9	4.6	2.1
723A	01-1486	M	E	74170	382	11.2	55	0.030	0.39	1.1	14.	31	2.2	1.5	0.70	4.3	3.5	1.6
694S	02-1364	F	B	74032	372	9.7	56	0.030	0.33	1.1	12.	32	2.2	2.8	1.3	5.7	7.3	3.3
859O	03-1748	M	I	75346	387	10.7	57	0.030	0.27	1.1	10.		1.6	1.9	0.90			
872V	01-1834	F	L	76079	443	8.9	58	0.020	0.19	0.74	7.0		1.3	1.0	0.50			
726S	03-1492	F	F	74172	379	8.5	59	0.020	0.17	0.74	6.3	20	1.3	1.4	0.70	4.1	4.5	2.1
858A	01-1744	M	I	75344	394	10.2	60	0.020	0.19	0.74	7.0		1.2	2.0	0.90			
703B	02-1442	M	C	74121	421	9.6	61	0.020	0.19	0.74	7.0	24	1.3	1.6	0.70	4.4	5.6	2.5
684S	01-1360	F	B	74030	416	10.1	62	0.020	0.17	0.74	6.3	23	1.1	1.2	0.60	3.8	4.6	2.1
724S	01-1492	F	F	74172	380	9.1	63	0.020	0.15	0.74	5.6	24	1.1	1.2	0.60	4.4	5.1	2.3
877S	02-1830	F	L	76077	413	10.7	64	0.010	0.15	0.37	5.6	23	0.90	0.90	0.40	3.6	3.6	1.7
725A	03-1486	M	E	74170	377	10.6	65	0.010	0.14	0.37	5.2		0.80	1.1	0.50			
685C	01-1364	M	A	74032	418	9.6	66	0.010	0.19	0.37	7.0	17	1.3	1.2	0.60	2.9	3.0	1.4
860S	02-1748	F	J	75346	385	10.2	67	0.010	0.11	0.37	4.1	25	0.70	0.70	0.30	4.1	4.3	2.0
747A	02-1550	M	G	74254	365	8.3	68	0.010	0.070	0.37	2.6	18	0.60	0.60	0.30	3.7	4.0	1.8
701C	03-1446	M	C	74123	431	8.8	69	0.010	0.070	0.37	2.6		0.50	0.80	0.40			
708V	03-1442	F	D	74121	407	8.2	70	0.010	0.050	0.37	1.9		0.40	0.60	0.30			
744T	03-1554	F	H	74256	377	7.4	71	0.010	0.040	0.37	1.5		0.30	0.30	0.10			
875B	02-1834	M	K	76079	428	11.4	72	0.003	0.030	0.11	1.1		0.20	0.30	0.10			
689U	02-1378	F	B	74038	415	9.1	C											
694C	01-1378	M	A	74038	378	7.9	C											
704A	02-1432	M	C	74113	408	10.2	C											
705S	01-1432	F	D	74113	407	5.5	C											
721A	01-1488	M	E	74170	384	13.0	C											
725S	02-1488	F	F	74170	377	10.1	C											
738C	01-1556	M	G	74263	419	9.6	C											
745S	02-1556	F	H	74263	378	9.6	C											
859C	02-1754	M	I	75344	385	11.3	C											
860T	01-1754	F	J	75344	383	9.2	C											
874U	01-1835	F	L	76078	429	9.4	C											
876B	02-1835	M	K	76078	422	11.4	C											

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
KBQ/KG REPRESENTS KILOBEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED RESPECTIVELY. PROMINENT FINDINGS ARE INCLU
(I) SIGNIFIES AN INCIDENTAL FINDING WHICH WAS NOT IMMEDIATELY LIFE-THEATENING.
CAUTION: THE RECONSTRUCTED INITIAL LUNG BURDENS, DENOTED BY (R) AND (REC) IN THIS TABLE MAY BE TOO HIGH BECAUSE OF CURRENT A
THIS MAY LEAD TO CALCULATED ORGAN DOSES THAT ARE TOO HIGH. THIS PROBLEM IS ESPECIALLY IMPORTANT FOR DOGS IN THE

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IVE ALPHA RADIATION

E TO DEATH (GY)

WBC) BONE	FROM ILB (REC.) LUNG	LIVER	BONE	DEATH DATE	DAYS TO DEATH	COMMENT
0.90	3.2	2.0	0.9	81163	2597	D-ACCIDENTAL DEATH
1.0	5.3	4.6	2.2	83010	3176	E-OSTEOSARCOMA,THOR. VERT. T11
1.1	5.3	5.0	2.2	83270	3527	D-UNDETERMINED
1.4				88218	4623	E-CHONDROSARC.,LIVER;OSTEOSARCOMA,SCAPULA
1.1	4.9	4.6	2.1	85043	3805	E-OSTEOSARCOMA,FEMUR;FIBROSARCOMA,LIVER
0.70	4.3	3.5	1.6	82260	3012	E-OSTEOSARCOMA,SCAPULA
1.3	5.7	7.3	3.3	87086	4802	E-LIVER HEPATOCELLULAR CARCINOMA
0.90				88358	4760	E-PYELONEPHRITIS
0.50				84276	3119	E-OSTEOSARCOMA,SACRUM;FIBROSARC.,LIVER
0.70	4.1	4.5	2.1	86168	4379	E-OSTEOSARCOMA,BONE;CARCINOMA,LUNG
0.90				91089	5589	E-MYELOPROLIFERATIVE DISEASE
0.70	4.4	5.6	2.5	87134	4761	E-FIBROSARCOMA,BONE
0.60	3.8	4.6	2.1	86183	4536	D-BRONCHOPNEUMONIA
0.60	4.4	5.1	2.3	86204	4415	E-CARCINOMA,LUNG
0.40	3.6	3.6	1.7	87054	3995	E-OSTEOSARCOMA,BONE
0.50				88099	5042	E-CARCINOMA,LIVER;CARCINOMA,LUNG
0.60	2.9	3.0	1.4	85130	4116	E-MELANOMA,MOUTH
0.30	4.1	4.3	2.0	87128	4164	E-OSTEOSARCOMA,BONE
0.30	3.7	4.0	1.8	86093	4222	D-CARCINOMA,INTESTINE
0.40				89338	5694	E-HEMANGIOSARCOMA, SUBCUTIS
0.30				89100	5458	E-DEGENERATIVE JOINT DISEASE;B.A. CARC.
0.10				84298	3694	E-MAST CELL TUMOR,MOUTH
0.10				90088	5123	E-CHRONIC NEPHRITIS
				87036	4746	E-CARCINOMA,LUNG
				90073	5879	E-ADENOMA, PITUITARY
				87254	4889	E-MAST CELL TUMOR DISSEMINATED
				77241	1224	E-MALABSORPTION SYNDROME
				76260	820	D-LEUCOENCEPHALOMALACIA
				87015	4593	D-CARCINOMA,BLADDER
				89329	5546	E-CHRONIC NEPHRITIS
				89038	5254	E-CHRONIC INTERSTITIAL NEPHRITIS
				87196	4235	E-CARCINOMA,LUNG
				87315	4354	E-ADENOMA,PITUITARY;BRONCHOPNEUMONIA,LUNG
				86241	3816	E-CIRRHOSIS,LIVER
				90080	5116	D-ANESTHETIC DEATH

OSURE.
OMINENT FINDINGS ARE INCLUDED.

OO HIGH BECAUSE OF CURRENT ANALYTICAL RADIOCHEMICAL PROBLEMS.
IMPORTANT FOR DOGS IN THE LOWER EXPOSURE LEVELS.

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A.18 $^{238}PuO_2$ Monodisperse Aerosol (3.0 μm AMAD), Longevity Study

DOG IDENTIFICATION		INHALATION EXPOSURE					ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RA DOSE TO DEATH (			
					AGE	WT							FROM ILB (WBC)			FRO
TATTOO	AN-EXPT	SEX	BLOCK	DATE	DAYS	KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	LUNG	LIVER	BONE	LUN
667T	01-1306	F	B	73347	433	7.1	01	1.50	11.	56.	400.	310.	120.	28.	13.	92.
710C	02-1460	M	E	74143	427	8.7	02	1.30	11.	48.	420.	360.	86.	9.6	4.8	70.
736A	02-1540	M	G	74249	414	10.1	03	0.93	9.3	34.	340.	380.	48.	17.	8.0	53.
667S	03-1306	F	B	73347	431	10.3	04	0.93	9.3	34.	340.	280.	48.	21.	9.8	37.
674B	03-1302	M	A	73345	403	9.4	05	0.80	7.3	30.	270.	220.	42.	21.	10.	35.
866A	02-1814	M	K	76062	441	12.3	06	0.80	[illegible]	30.	350.	510.	41.	16.	7.6	58.
696A	03-1428	M	C	74113	433	10.8	07	0.73	[illegible]	27.	300.	240.	40.	18.	8.7	31.
849S	02-1720	F	J	75324	424	8.2	08	0.65	5.3	24.	200.	200.	34.	12.	5.3	33.
731S	01-1540	F	H	74249	437	6.5	09	0.60	3.9	22.	140.	140.	32.	11.	5.1	32.
711S	01-1456	F	F	74141	423	7.2	10	0.58	4.2	21.	160.	160.	31.	15.	6.9	31.
703S	01-1436	F	D	74115	415	7.5	11	0.53	3.9	20.	140.	93.	28.	13.	6.3	17.
736S	03-1538	F	H	74247	412	7.9	12	0.52	4.1	19.	150.	300.	39.	7.3	3.5	74.
696S	03-1436	F	D	74115	435	5.4	13	0.44	2.4	16.	89.	78.	24.	12.	5.5	21.
682V	02-1302	F	B	73345	373	8.3	14	0.41	3.4	15.	130.	130.	22.	10.	4.9	21.
852B	01-1720	M	I	75324	409	10.3	15	0.41	4.1	15.	150.	160.	21.	11.	5.3	17.
716T	02-1456	F	F	74141	393	8.8	16	0.41	3.6	15.	130.	140.	22.	9.2	4.4	23.
674A	01-1302	M	A	73345	404	10.6	17	0.39	4.2	14.	160.	140.	21.	9.8	4.7	19.
680B	02-1306	M	A	73347	393	10.0	18	0.39	3.9	14.	140.	89.	22.	13.	6.5	13.
695A	01-1428	M	C	74113	442	12.4	19	0.38	4.7	14.	170.	130.	21.	12.	5.7	16.
865S	01-1814	F	L	76062	442	7.2	20	0.38	2.7	14.	100.	130.	20.	10.	4.8	30.
697B	02-1436	M	C	74115	430	12.7	21	0.34	4.3	13.	160.	110.	18.	5.1	2.5	12.
708A	03-1456	M	E	74141	427	11.0	22	0.32	3.5	12.	130.	130.	17.	7.1	3.4	18.
867A	01-1818	M	K	76064	432	12.4	23	0.31	3.9	11.	140.	170.	17.	8.0	3.8	20.
846A	03-1720	M	I	75324	431	12.7	24	0.29	3.6	11.	130.	130.	15.	6.2	2.9	11.
715B	03-1460	M	E	74143	396	9.8	25	0.23	2.2	8.5	81.	89.	2.1	6.1	3.0	13.
730S	01-1542	F	H	74252	442	10.6	26	0.21	2.3	7.8	85.	85.	17.	6.9	3.3	18.
870V	03-1814	F	L	76062	426	11.7	27	0.21	2.5	7.8	93.	140.	12.	6.0	2.9	20.
733A	04-1538	M	G	74247	431	9.9	28	0.18	1.8	6.7	67.	110.	9.5	3.3	1.6	16.
736E	02-1538	M	G	74247	412	9.4	29	0.17	1.9	6.3	70.	130.	11.	3.5	2.6	19.
846B	02-1716	M	I	75322	429	9.6	30	0.17	1.7	6.3	63.	70.	9.6	5.1	2.5	7.
715A	02-1462	M	E	74144	397	8.8	31	0.17	1.5	6.3	56.	56.	9.5	5.8	2.9	8.
678T	01-1304	F	B	73346	398	8.1	32	0.17	1.4	6.3	52.	48.	9.6	7.3	3.5	10.
848S	01-1722	F	J	75325	427	9.6	33	0.16	1.5	5.9	56.	28.	8.9	8.1	3.8	4.
869T	03-1818	F	L	76064	431	7.5	34	0.13	1.0	4.8	37.	63.	7.2	4.1	2.0	13.
696D	01-1438	M	C	74116	436	6.7	35	0.13	0.93	4.8	34.	41.	7.8	6.0	2.9	9.
714U	01-1460	F	F	74143	402	6.6	36	0.11	0.67	4.1	25.	41.	5.9	5.5	2.7	9.
674C	02-1308	M	A	73348	407	10.1	37	0.090	1.0	3.3	37.	44.	5.7	5.5	2.6	6.
680A	03-1308	M	A	73348	394	11.5	38	0.090	1.1	3.3	41.	44.	5.3	3.6	1.7	5.
848T	01-1716	F	J	75322	424	7.7	39	0.090	0.73	3.3	27.	41.	5.4	4.8	2.3	8.
865D	02-1818	M	K	76064	444	10.2	40	0.090	0.87	3.3	32.	52.	4.8	3.5	1.7	8.
874A	02-1820	M	K	76065	416	13.3	41	0.070	1.0	2.6	37.	59.	4.7	3.2	1.6	9.
702S	03-1434	F	D	74114	415	8.1	42	0.070	0.60	2.6	22.	37.	4.2	4.0	1.9	5.
846C	03-1718	M	I	75323	431	9.2	43	0.070	0.73	2.6	27.	41.	4.5	4.5	1.8	6.
711T	01-1458	F	F	74142	424	6.5	44	0.070	0.49	2.6	18.	35.	4.4	4.6	2.3	8.
733S	02-1542	F	H	74252	436	8.8	45	0.070	0.67	2.6	25.	37.	4.4	4.9	2.3	6.
854B	01-1718	M	I	75323	396	7.6	46	0.070	0.51	2.6	19.	33.	3.9	4.0	1.8	6.
856T	03-1716	F	J	75322	378	5.8	47	0.070	0.40	2.6	15.	30.	3.9	4.0	1.8	8.
869U	02-1816	F	L	76063	430	8.4	48	0.060	0.52	2.2	19.	37.	3.3	1.9	1.5	6.
735C	04-1540	M	G	74249	424	10.5	49	0.060	0.58	2.2	21.	35.	3.2	3.6	1.7	5.

CUMULATIVE ALPHA RADIATION DOSE TO DEATH (GY)								
FROM ILB (WBC)			FROM ILB (REC.)			DEATH DATE	DAYS TO DEATH	COMMENT
LUNG	LIVER	BONE	LUNG	LIVER	BONE			
120.	28.	13.	92.	22.	11.	77099	1213	D-PNEUMONITIS AND PULMONARY FIBROSIS
86.	9.6	4.8	70.	7.8	3.9	76044	631	E-PNEUMONITIS AND PULMONARY FIBROSIS
48.	17.	8.0	53.	18.	8.8	77334	1181	E-OSTEOSAR.,LUM. VERT.;CARCINOMA,LUNG
48.	21.	9.8	37.	16.	7.6	77318	1432	E-OSTEOSARC.,CERV. VERT.;CARC.,LUNG(I)
42.	21.	10.	35.	17.	8.3	78202	1683	D-PNEUM. AND PUL. FIBROS.;CARC.,LUNG(I)
41.	16.	7.6	58.	23.	11.	79285	1319	E-CARCINOMA,LUNG
40.	18.	8.7	31.	14.	6.7	78180	1528	E-OSTEOSARCOMA,HUMERUS AND PALATINE
34.	12.	5.3	33.	11.	5.1	79047	1184	E-OSTEOSARCOMA,THOR. VERT. AND SACRUM
32.	11.	5.1	32.	11.	5.1	77314	1161	E-OSTEOSARCOMA,TIBIA AND FEMUR
31.	15.	6.9	31.	14.	6.8	78223	1543	E-OSTEOSARCOMA,ILIUM
28.	13.	6.3	17.	8.1	3.9	78222	1568	E-OSTEOSARCOMA,LUMBAR VERTEBRAE
39.	7.3	3.5	74.	14.	6.7	77117	966	D-PNEUM. AND PUL. FIBROS.;CARC.,LUNG(I)
24.	12.	5.5	21.	10.	4.8	78264	1610	E-OSTEOSARCOMA,HUMERUS
22.	10.	4.9	21.	9.9	4.7	78069	1550	E-OSTEOSARCOMA,LUMBAR VERTEBRAE
21.	11.	5.3	17.	8.8	4.3	80205	1707	E-BONE TUMORS,T8 AND C7
22.	9.2	4.4	23.	9.7	4.7	78096	1416	E-OSTEOSARCOMA,ISCHIUM AND ILIUM
21.	9.8	4.7	19.	8.7	4.2	78075	1556	E-OSTEOSARC.,CERV.VERT.,SCAP.;CARC.,LUNG
22.	13.	6.5	13.	7.8	3.9	79299	2143	D-CARCINOMA,LUNG
21.	12.	5.7	16.	9.3	4.5	79205	1918	D-OSTEOSARCOMA,HUMERI
20.	10.	4.8	30.	15.	7.2	80273	1672	E-BONE TUMORS,L4,ILIUM,SCAP.;CARC.,LUNG
18.	5.1	2.5	12.	3.5	1.7	77144	1125	E-OSTEOSARCOMA,CERVICAL VERTEBRAE
17.	7.1	3.4	18.	7.3	3.5	78089	1409	E-OSTEOSARCOMA,THORACIC VERTEBRAE
17.	8.0	3.8	20.	9.2	4.4	80191	1588	E-BONE TUMORS,HUMERI
15.	6.2	2.9	11.	4.6	2.2	79235	1372	E-OSTEOSARCOMA,THORACIC VERTEBRAE
2.1	6.1	3.0	13.	6.4	3.1	79016	1699	E-OSTEOSARCOMA,HUMERUS
17.	6.9	3.3	18.	7.2	3.4	80038	1977	D-PNEUMONITIS
12.	6.0	2.9	20.	11.	5.0	80330	1729	E-OSTEOSARCOMA,FEMUR;CARCINOMA,LUNG
9.5	3.3	1.6	16.	5.5	2.7	77353	1202	E-OSTEOSARCOMA,SACRUM,STERNUM AND FEMUR
11.	3.5	2.6	19.	6.0	4.5	79101	1680	E-OSTEOSARCOMA,HUMERUS
9.6	5.1	2.5	7.9	4.2	2.0	80274	1778	E-BONE TUMORS,HUMERUS
9.5	5.8	2.9	8.8	5.4	2.7	80129	2176	E-BONE TUMOR,HUMERUS
9.6	7.3	3.5	10.	7.8	3.6	81161	2737	D-OSTEOSARC.,HUMERI,T6-T12;CARC.,LUNG
8.9	8.1	3.8	4.5	4.0	1.9	85123	3451	E-OSTEOSARCOMA,FEMUR;CARCINOMA,LUNG
7.2	4.1	2.0	13.	7.3	3.6	81210	1973	E-OSTEOSARCOMA,VERT. L2
7.8	6.0	2.9	9.2	7.5	3.6	82152	2958	E-OSTEOSARCOMA,FRONTAL BONE
5.9	5.5	2.7	9.5	8.5	4.1	84023	3532	E-OSTEOSARC.,SCAP.,HUMER.;B.A.CARC.,LUNG
5.7	5.5	2.6	6.8	6.8	3.1	84072	3741	E-OSTEOSARCOMA,HUMERUS
5.3	3.6	1.7	5.3	3.6	1.7	80177	2385	E-OSTEOSARCOMA,L6;CARCINOMA,LUNG
5.4	4.8	2.3	8.1	7.1	3.4	85022	3353	E-OSTEOSARCOMA,RIB
4.8	3.5	1.7	8.7	5.4	2.6	83131	2624	E-KIDNEY ATROPHY
4.7	3.2	1.6	9.2	7.1	3.4	83343	2835	E-OSTEOSARC.,VERT. L6;ADENOCARC.,LUNG
4.2	4.0	1.9	5.7	5.4	2.6	84074	3612	E-OSTEOSARCOMA,SCAPULA
4.5	4.5	1.8	6.8	6.2	3.0	85290	3620	D-MYOCARDIAL DEGENERATION,HEART
4.4	4.6	2.3	8.5	8.9	4.2	85166	4042	D-CARCINOMA,LUNG
4.4	4.9	2.3	6.6	6.9	3.3	85238	4054	E-CARCINOMA,LUNG
3.9	4.0	1.8	6.6	6.2	3.1	86136	3831	E-OSTEOSARCOMA,BONE
3.9	4.0	1.8	8.0	7.5	3.8	86108	3804	E-OSTEOSARCOMA,BONE
3.3	1.9	1.5	6.2	3.5	2.9	81138	1902	D-EPILEPSY
3.2	3.6	1.7	5.2	5.6	1.9	86100	4234	E-CARCINOMA,LUNG

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A.18 $^{238}PuO_2$ Monodisperse Aerosol (3.0 μm AMAD), Longevity Study (continued)

DOG IDENTIFICATION			INHALATION EXPOSURE				ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RADIATION DOSE TO DEATH (GY)				
					AGE	WT							FROM	ILB (WBC)		FROM	ILB (RI
TATTOO	AN-EXPT	SEX	BLOCK	DATE	DAYS	KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	LUNG	LIVER	BONE	LUNG	LIVER
732A	01-1538	M	G	74247	434	11.0	50	0.060	0.61	2.2	23.	48.	3.1	2.1	1.0	6.6	4.2
697A	03-1438	M	C	74116	431	10.4	51	0.050	0.55	1.9	20.	37.	3.1	3.8	1.7	5.6	6.0
680T	03-1304	F	B	73346	392	6.7	52	0.050	0.31	1.9	11.	24.	2.7	2.8	1.4	3.6	4.3
705C	03-1458	M	E	74142	436	9.3	53	0.040	0.40	1.5	15.	26.	2.4	2.0	0.90	4.0	3.2
872S	01-1820	F	L	76065	429	11.3	54	0.040	0.46	1.5	17.	35.	2.3	2.1	1.0	4.7	4.2
697S	02-1434	F	D	74114	429	8.0	55	0.040	0.31	1.5	11.	21.	2.2	1.9	0.90	3.2	2.7
715S	01-1462	F	F	74144	397	7.2	56	0.040	0.26	1.5	9.6	27.	2.1	2.9	1.4	5.8	8.1
704S	02-1428	F	D	74113	408	9.5	57	0.040	0.34	1.5	13.	26.	2.1	1.9	0.90	4.0	3.8
857S	02-1722	F	J	75325	377	11.8	58	0.030	0.40	1.1	15.	21.	1.8	0.80	0.40	2.5	1.1
714S	03-1462	F	F	74144	403	8.4	59	0.030	0.25	1.1	9.3	21.	1.7	1.8	0.80	3.9	3.7
734S	03-1542	F	H	74252	435	9.8	60	0.030	0.26	1.1	9.6	23.	1.6	1.6	0.70	3.6	3.8
871B	01-1816	M	K	76063	427	12.1	61	0.020	0.26	0.74	9.6		1.2	1.7	0.80		
679B	01-1308	M	A	73348	396	9.2	62	0.020	0.18	0.74	6.7	25.	1.1	1.4	0.60	4.3	5.6
865B	03-1816	M	K	76063	443	12.4	63	0.020	0.22	0.74	8.1		1.0	1.4	0.60		
849C	02-1718	M	I	75323	424	9.9	64	0.020	0.17	0.74	6.3	17.	1.0	0.80	0.40	2.6	2.0
856S	03-1722	F	J	75325	381	8.9	65	0.020	0.15	0.74	5.6		1.0	1.4	0.60		
732B	04-1542	M	G	74252	439	11.2	66	0.020	0.19	0.74	7.0	20.	0.90	0.50	0.30	2.6	1.5
680S	02-1304	F	B	73346	392	7.9	67	0.020	0.13	0.74	4.8	21.	0.90	1.4	0.60	4.3	6.1
699S	02-1438	F	D	74116	430	9.1	68	0.020	0.14	0.74	5.2	24.	0.90	1.2	0.60	4.1	5.8
734T	03-1540	F	H	74249	432	9.4	69	0.010	0.13	0.37	4.8	20.	0.80	0.90	0.40	3.4	3.6
870T	03-1820	F	L	76065	429	9.2	70	0.010	0.11	0.37	4.1	9.3	0.70	0.50	0.20	1.5	1.0
697D	01-1434	M	C	74114	429	10.2	71	0.010	0.080	0.37	3.0	18.	0.50	0.50	0.20	2.8	3.0
708C	02-1458	M	E	74142	428	7.8	72	0.010	0.040	0.37	1.5		0.30	0.60	0.20		
679S	02-1309	F	B	73348	396	7.4	C										
681E	01-1309	M	A	73348	381	9.5	C										
696C	01-1430	M	C	74113	433	8.3	C										
702U	02-1430	F	D	74113	414	8.9	C										
710A	02-1472	M	E	74150	434	11.4	C										
718T	01-1472	F	F	74150	387	7.4	C										
736B	01-1536	M	G	74241	407	10.5	C										
733T	02-1536	F	H	74242	426	7.5	C										
848A	02-1724	M	I	75329	431	8.8	C										
857U	01-1724	F	J	75329	381	9.4	C										
870U	01-1823	F	L	76063	400	10.0	C										
871A	02-1823	M	K	76063	400	10.0	C										

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
KBQ/KG REPRESENTS KILOBEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED RESPECTIVELY. PROMINENT FINDINGS ARE
(I) SIGNIFIES AN INCIDENTAL FINDING WHICH WAS NOT IMMEDIATELY LIFE-THEATENING.
CAUTION: THE RECONSTRUCTED INITIAL LUNG BURDENS, DENOTED BY (R) AND (REC) IN THIS TABLE MAY BE TOO HIGH BECAUSE OF CUR
THIS MAY LEAD TO CALCULATED ORGAN DOSES THAT ARE TOO HIGH. THIS PROBLEM IS ESPECIALLY IMPORTANT FOR DOGS I

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:UMULATIVE ALPHA RADIATION

DOSE TO DEATH (GY)

' ILB (WBC) LIVER	BONE	FROM ILB (REC.) LUNG	LIVER	BONE	DEATH DATE	DAYS TO DEATH	COMMENT
2.1	1.0	6.6	4.2	2.0	81103	2413	E-OSTEOSARCOMA,VERT. L5 AND S1
3.8	1.7	5.6	6.0	3.1	86119	4386	E-DISC PROTRUSION;CARCINOMA,LUNG
2.8	1.4	3.6	4.3	1.9	85086	4123	E-OSTEOSARCOMA,SACRUM
2.0	0.90	4.0	3.2	1.5	82266	3046	D-LYMPHOSARCOMA,VISCERAL
2.1	1.0	4.7	4.2	2.0	85214	3437	E-CHONDROSARCOMA,SCAPULA
1.9	0.90	3.2	2.7	1.5	83049	3222	E-PANCREATITIS
2.9	1.4	5.8	8.1	3.8	87211	4815	E-OSTEOSARCOMA,BONE
1.9	0.90	4.0	3.8	1.8	84027	3566	E-UNDIFF. SARC.,RIB;NEUROFIBROSARC.,LIV.
0.80	0.40	2.5	1.1	0.5	80024	1525	D-EPILEPSY
1.8	0.80	3.9	3.7	1.9	85005	3879	E-OSTEOSARCOMA,VERTEBRA;CARCINOMA,LUNG
1.6	0.70	3.6	3.8	1.7	85065	3831	E-OSTEOSARCOMA,VERTEBRA
1.7	0.80				89040	4726	E-CHRONIC INTER. NEPHRITIS;AORT. THROMB.
1.4	0.60	4.3	5.6	2.4	85310	4345	E-OSTEOSARCOMA,BONE
1.4	0.60				88257	4577	E-ADENOCARCINOMA,RECTUM;NEPHROPATHY
0.80	0.40	2.6	2.0	1.0	84079	3043	E-MELANOMA,SKIN
1.4	0.60				88326	4749	E-CHONDRO. OSTEOSARC,HUM.;PAP. ADCA.,LUNG
0.50	0.30	2.6	1.5	0.7	80015	1954	D-GASTRIC FOREIGN BODY
1.4	0.60	4.3	6.1	2.9	87183	4950	E-CARCINOMA,MAMMARY;CARCINOMA,LUNG
1.2	0.60	4.1	5.8	2.7	87216	4848	D-PNEUMONIA
0.90	0.40	3.4	3.6	1.9	86346	4480	E-CARCINOMA,LUNG
0.50	0.20	1.5	1.0	0.5	83162	2654	D-PYOMETRA
0.50	0.20	2.8	3.0	1.4	85149	4053	D-THROMBOSIS,AORTA
0.60	0.20				90086	5788	E-ANKYLOSING SPONDYLOSIS;ADENOCARCINOMA, L
					86127	4527	E-CARCINOMA,MAMMARY
					88280	5410	D-INTERVERT. DISC DISEASE;BRONCHOPNEUM.
					87100	4735	E-PYELONEPHRITIS
					89087	5453	E-CHOLANGIOHEPATITIS
					86335	4568	D-ACUTE NEPHROSIS
					88231	5194	E-CARCINOMA,MAMMARY GLAND
					87119	4626	D-PULMONARY EDEMA
					82223	2903	E-LYMPHOSARCOMA,SKIN
					87087	4141	D-HEMANGIOSARCOMA,HEART
					80030	1527	D-EPILEPSY
					85063	3288	D-PYOMETRA
					87187	4142	E-ADENOMA,PITUITARY

)N EXPOSURE.
'. PROMINENT FINDINGS ARE INCLUDED.

' BE TOO HIGH BECAUSE OF CURRENT ANALYTICAL RADIOCHEMICAL PROBLEMS.
:IALLY IMPORTANT FOR DOGS IN THE LOWER EXPOSURE LEVELS.

2

(1)

A.19 $^{239}PuO_2$ Monodisperse Aerosol (0.75 μm AMAD), Longevity Study

DOG IDENTIFICATION		INHALATION EXPOSURE					ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RADIATION DOSE		
													TO 9-30-91	TO DEATH	
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	WBC LUNG	WBC LUNG	REC. LUNG
1134C	01-2686	M	K	78325	385	8.9	01	0.20	1.8	7.4	67.	100			41
1142V	01-2730	F	L	79052	421	9.1	02	0.19	1.7	7.0	63.	63			29
1109B	01-2560	M	I	78165	367	10.6	03	0.18	1.9	6.7	70.	63			30
1136A	03-2690	M	K	78326	368	10.4	04	0.17	1.8	6.3	67.	63			31
992B	01-2106	M	C	77069	399	10.8	05	0.16	1.7	5.9	63.	67			24
1092S	01-2528	F	H	78144	411	9.5	06	0.16	1.5	5.9	56.	59			29
1027U	01-2236	F	F	77216	421	10.3	07	0.15	1.5	5.6	56.	31			21
1125S	01-2610	F	J	78248	374	8.2	08	0.15	1.2	5.6	44.	41			23
1122T	03-2612	F	J	78244	388	7.6	09	0.11	0.87	4.1	32.	33			22
1107A	03-2562	M	I	78166	375	12.4	10	0.10	1.2	3.7	44.	56			26
1028U	03-2238	F	F	77217	421	8.7	11	0.10	0.87	3.7	32.	17			14
1097E	01-2534	M	G	78150	396	8.9	12	0.10	0.87	3.7	32.			23.	
980T	03-2082	F	B	77035	410	9.7	13	0.096	0.93	3.6	34.	44			23
1006B	01-2148	M	E	77118	373	8.5	14	0.079	0.67	2.9	25.	30			21
1098C	03-2536	M	G	78151	391	8.6	15	0.073	0.63	2.7	23.	34			24
996U	02-2174	F	D	77140	446	7.1	16	0.073	0.52	2.7	19.	19			18
963E	02-1954	M	A	77007	439	11.5	17	0.063	0.73	2.3	27.			15.	
999S	01-2172	F	D	77139	423	8.2	18	0.062	0.51	2.3	19.	30			26
1005C	03-2150	M	E	77119	377	10.3	19	0.062	0.64	2.3	24.	37			22
1001T	01-2174	F	D	77140	409	10.6	20	0.059	0.63	2.2	23.	31			18
990C	02-2108	M	C	77070	410	9.3	21	0.055	0.51	2.0	19.	23			15
1023W	02-2238	F	F	77217	438	9.4	22	0.054	0.51	2.0	19.	18			13
1130B	02-2690	M	K	78326	403	10.5	23	0.051	0.54	1.9	20.			14.	
1145T	03-2732	F	L	79053	414	9.8	24	0.049	0.48	1.8	18.	24			17
990A	01-2108	M	C	77070	410	9.5	25	0.047	0.45	1.7	17.	81			47
1006A	01-2150	M	E	77119	374	8.5	26	0.046	0.39	1.7	14.	21			18
1096S	03-2532	F	H	78145	395	8.6	27	0.043	0.37	1.6	14.			12.	
1143T	02-2732	F	L	79053	418	8.9	28	0.042	0.37	1.6	14.			11.	
963F	01-1954	M	A	77007	439	11.4	29	0.041	0.47	1.5	17.	22			14
1097C	02-2536	M	G	78151	397	9.0	30	0.041	0.37	1.5	14.			9.9	
1134B	01-2690	M	K	78326	386	10.0	31	0.040	0.40	1.5	15.			11.	
1121S	02-2612	F	J	78244	401	8.5	32	0.039	0.33	1.4	12.	23			19
1100B	02-2562	M	I	78166	399	9.5	33	0.028	0.27	1.0	10.			8.0	
970D	01-1952	M	A	77006	424	10.4	34	0.026	0.27	0.96	10.			7.6	
1096U	02-2532	F	H	78145	395	8.2	35	0.024	0.20	0.89	7.4			7.0	
969A	03-1954	M	A	77007	426	10.1	36	0.023	0.23	0.85	8.5			6.8	
982T	02-2082	F	B	77035	404	9.9	37	0.021	0.21	0.78	7.8			6.2	
1111B	01-2562	M	I	78166	365	9.7	38	0.021	0.20	0.78	7.4			5.8	
1125T	01-2612	F	J	78244	370	8.1	39	0.021	0.17	0.78	6.3			6.0	
976T	01-2080	F	B	77034	431	10.3	40	0.019	0.20	0.70	7.4			6.0	
977S	01-2082	F	B	77035	430	7.4	41	0.018	0.13	0.67	4.8			5.4	
1005D	02-2150	M	E	77119	377	9.6	42	0.015.	0.14	0.55	5.2			3.8	
1143S	01-2732	F	L	79053	418	11.0	43	0.014	0.15	0.52	5.6			4.0	
1094T	01-2532	F	H	78145	401	10.6	44	0.010	0.11	0.37	4.1			3.0	
1028S	01-2238	F	F	77217	421	9.4	45	0.010	0.090	0.37	3.3			2.9	
988C	03-2108	M	C	77070	425	9.3	46	0.010	0.090	0.37	3.3			2.8	
996T	03-2174	F	D	77140	446	8.8	47	0.0080	0.070	0.30	2.6			2.4	
1096A	01-2536	M	G	78151	401	10.8	48	0.0060	0.070	0.22	2.6			2.0	
961A	03-1956	M	A	77007	448	11.0	C								
980S	02-2084	F	B	77035	410	8.4	C								
992A	02-2116	M	C	77080	406	10.0	C								
1007C	02-2146	M	E	77117	371	9.5	C								
999U	02-2168	F	D	77130	414	10.3	C								
1022W	02-2240	F	F	77231	423	7.2	C								
1095T	01-2530	F	H	78144	400	10.6	C								
1098A	01-2535	M	G	78150	390	9.9	C								
1106A	01-2564	M	I	78165	382	9.8	C								
1121T	02-2614	F	J	78244	405	9.6	C								
1131D	01-2688	M	K	78325	392	6.8	C								
1146S	01-2733	F	L	79052	408	11.0	C								

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
KBQ/KG REPRESENTS KILOBEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED RESPECTIVELY. PROMINENT FINDINGS ARE
(I) SIGNIFIES AN INCIDENTAL FINDING WHICH WAS NOT IMMEDIATELY LIFE-THEATENING.
CAUTION: THE RECONSTRUCTED INITIAL LUNG BURDENS, DENOTED BY (R) AND (REC) IN THIS TABLE MAY BE TOO HIGH BECAUSE OF CURI
THIS MAY LEAD TO CALCULATED ORGAN DOSES THAT ARE TOO HIGH. THIS PROBLEM IS ESPECIALLY IMPORTANT FOR DOGS I

2

TIVE ALPHA RADIATION DOSE (GY)

9-30-91 WBC LUNG	TO DEATH WBC LUNG	REC. LUNG	DEATH DATE	DAYS TO 9-30 1991	DAYS TO DEATH	COMMENT
		41	81120		891	E-PNEUMONITIS AND PULMONARY FIBROSIS
		29	82137		1181	E-PNEUMONITIS AND PULMONARY FIBROSIS
		30	82224		1520	D-RAD.PNEUM.;PUL.FIB.;PULMONARY CARC.
		31	82332		1467	D-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
		24	80009		1035	D-PNEUMONITIS
		29	82054		1371	E-PNEUMONITIS AND PULMONARY FIBROSIS
		21	85073		2779	E-MENINGOMA,BRAIN;CARCINOMA,LUNG
		23	82067		1280	E-PNEUMONITIS AND PULMONARY FIBROSIS
		22	82308		1525	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
		26	83097		1757	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
		14	85037		2742	E-CARCINOMA AND FIBROSARCOMA,LUNG
	23.		84240		2281	E-FIBROSARC.,MEDIAST.;B.A. CARC.,LUNG
		23	81153		1579	E-PNEUM. AND PUL. FIBROS.;CARC.,LUNG
		21	82253		1961	E-FIBROSARCOMA,MUSCLE;PUL.CARCINOMA
		24	83356		2031	E-PNEUMONITIS;B.A. CARCINOMA,LUNG
		18	84030		2446	E-BRONCHIOLOALVELCAR CARCINOMA,LUNG
	15.		82357		2176	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
		26	85103		2836	D-BRONCHIOALVEOLAR CARCINOMA,LUNG
		22	83013		2085	D-PULMONARY CARCINOMA;PUL. FIBROSIS
		18	83030		2081	E-PULMONARY CARCINOMA;PUL. FIBROSIS
		15	82251		2007	D-HEMORRHAGIC ENTERITIS
		13	85036		2741	D-PNEUM. AND PUL. FIBROSIS;CARC., LUNG
	14.		87132		3093	E-CARCINOMA,LUNG
		17	86059		2563	E-CARCINOMA,LUNG
		47	81327		1718	E-PNEUMONITIS AND PULMONARY FIBROSIS
		18	86202		3370	D-CARCINOMA,LUNG
	12.		86338		3115	E-CARCINOMA,LUNG
	11.		87082		2951	D-CARCINOMA,LUNG
		14	86022		3302	E-CARCINOMA,LUNG
	9.9		84303		2343	E-ADENOCARCINOMA,PANCREAS
	11.		87133		3094	E-CARCINOMA,LUNG
		19	86074		2752	E-CARCINOMA,LUNG
	8.0		87308		3429	E-CARCINOMA,LUNG
	7.6		87251		3897	E-CARCINOMA,LUNG
	7.0		88154		3661	E-CARCINOMA,LUNG
	6.8		88152		4162	E-CARCINOMA,LUNG
	6.2		87151		3768	D-CARCINOMA,LUNG
	5.8		87256		3375	E-CARCINOMA,LUNG
	6.0		88053		3461	D-HEMANGIOSARCOMA,KIDNEY
	6.0		89177		4526	D-EXUDATIVE PNEUMONIA,LUNG
	5.4		89270		4618	E-PAPILLARY ADENOCARCINOMA,LUNG
	3.8		88273		4171	E-CARCINOMA,LUNG
	4.0		90005		3970	E-ADENOCARCINOMA,MAMMARY GLAND
	3.0		88082		3589	D-CARCINOMA,LUNG
	2.9		88357		4157	D-PAPILLARY ADENOCARCINOMA,LUNG
	2.8		87044		3626	E-MALIGNANT MELANOMA,MOUTH
	2.4		89032		4275	E-PAPILLARY ADENOCARCINOMA,LUNG
	2.0		90256		4488	D-BRONCHIOLOALVEOLAR CARCINOMA,LUNG
			90243		4977	D-HYPERADRENOCORTICISM
			86357		3609	D-MAST CELL SARCOMA
				5306		
			82184		1893	D-EPILEPSY
			85214		3006	D-PERITONITIS
			90094		4611	E-PROLAPSE,INTERVERTEBRAL DISCS
				4877		
			89156		4024	E-PROSTATITIS,RENAL FAILURE
				4853		
			87306		3349	D-THROMBOSIS,LUNG
			90317		4375	E-BRONCHOPNEUMONIA
				4604		

'N EXPOSURE.
. PROMINENT FINDINGS ARE INCLUDED.

BE TOO HIGH BECAUSE OF CURRENT ANALYTICAL RADIOCHEMICAL PROBLEMS.
IALLY IMPORTANT FOR DOGS IN THE LOWER EXPOSURE LEVELS.

A.20 $^{239}PuO_2$ Monodisperse Aerosol (1.5 μm AMAD), Longevity Study

DOG IDENTIFICATION		INHALATION EXPOSURE					ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RADIATION DOSE (GY)		
													TO 9-30-91	TO DEATH	
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	WBC LUNG	WBC LUNG	REC. LUNG
1155S	03-2744	F	L	79067	390	7.7	01	1.0	8.0	37.	300.	270.			40.
1110U	02-2592	F	H	78208	410	6.7	02	1.0	6.7	37.	250.	190.			31.
1137S	02-2726	F	J	79047	448	10.2	03	0.91	9.3	34.	340.	470.			60.
1101S	01-2592	F	H	78208	438	10.1	04	0.86	8.7	32.	320.	96.			17.
964S	01-1962	F	B	77013	444	8.9	05	0.85	7.6	31.	280.	330.			63.
990U	01-2114	F	D	77076	416	8.5	06	0.79	6.7	29.	250.	210.			59.
1117B	02-2604	M	I	78215	393	9.9	07	0.78	7.7	29.	280.	270.			32.
972A	02-1972	M	A	77020	436	10.0	08	0.57	5.7	21.	210.	150.			41.
1097B	04-2514	M	G	78117	363	9.7	09	0.57	5.5	21.	200.	190.			28.
1155T	02-2744	F	L	79067	390	6.7	10	0.51	3.4	19.	130.	170.			66.
996A	01-2132	M	C	77111	417	10.6	11	0.48	5.1	18.	190.	170.			45.
1015B	01-2196	M	E	77160	394	8.9	12	0.46	4.1	17.	150.	180.			40.
1027A	03-2196	M	E	77160	365	10.9	13	0.45	4.9	17.	180.	160.			56.
1099B	03-2602	M	I	78214	451	10.5	14	0.44	4.6	16.	170.	190.			34.
1110B	01-2604	M	I	78215	417	7.7	15	0.44	3.4	16.	130.	140.			36.
995C	03-2132	M	C	77111	433	9.9	16	0.40	4.0	15.	150.	110.			59.
1096C	03-2514	M	G	78117	367	9.8	17	0.38	3.7	14.	140.	130.			54.
1141U	03-2724	F	J	79046	429	6.7	18	0.33	2.2	12.	81.	93.			50.
977B	03-1972	M	A	77020	415	11.6	19	0.31	3.6	11.	130.	130.			27.
1092B	02-2514	M	G	78116	384	9.9	20	0.30	3.0	11.	110.	130.			47.
1023X	01-2210	F	F	77174	395	8.5	21	0.29	2.5	11.	93.	96.			35.
994S	02-2114	F	D	77076	401	9.3	22	0.29	2.7	11.	100.	81.			30.
1099V	02-2590	F	H	78207	414	8.9	23	0.24	2.1	8.9	78.	59.			27.
997C	02-2132	M	C	77111	416	10.3	24	0.23	2.4	8.5	89.	81.			40.
1134D	03-2684	M	K	78321	381	10.5	25	0.19	2.0	7.0	74.	70.			5.6
1141S	01-2726	F	J	79047	430	10.0	26	0.19	1.9	7.0	70.	190.			32.
1095S	03-2588	F	H	78206	462	10.1	27	0.19	1.9	7.0	70.			64.	
1099T	02-2588	F	H	78206	443	8.5	28	0.19	1.6	7.0	59.		73.		
989T	03-2114	F	D	77076	425	6.7	29	0.19	1.3	7.0	48.			45.	
1148U	01-2744	F	L	79067	414	6.7	30	0.19	1.3	7.0	48.			43.	
965S	02-1962	F	B	77013	444	10.0	31	0.17	1.7	6.3	63.			44.	
964T	03-1962	F	B	77013	444	7.7	32	0.17	1.3	6.3	48.	37.			27.
1009T	01-2208	F	F	77173	421	10.8	33	0.16	1.7	5.9	63.			39.	
1023B	02-2196	M	E	77160	381	10.0	34	0.15	1.5	5.6	56.			37.	
970A	01-1972	M	A	77020	438	10.3	35	0.15	1.5	5.6	56.			36.	
976A	01-1970	M	A	77019	419	12.6	36	0.14	1.8	5.2	67.	44.			20.
1020T	02-2210	F	F	77174	399	9.2	37	0.14	1.3	5.2	48.	41.			20.
1160T	03-2742	F	L	79066	368	8.3	38	0.13	1.1	4.8	41.			29.	
994T	03-2112	F	D	77075	400	8.8	39	0.13	1.1	4.8	41.			33.	
995A	03-2130	M	C	77110	432	10.4	40	0.12	1.2	4.4	44.			35.	
1008S	03-2210	F	F	77174	425	9.9	41	0.11	1.1	4.1	41.			31.	
1120A	02-2602	M	I	78214	382	9.3	42	0.11	1.0	4.1	37.			25.	
1112W	03-2590	F	H	78207	402	8.2	43	0.11	0.93	4.1	34.	63.			36.
1130A	03-2682	M	K	78320	397	10.5	44	0.10	1.1	3.7	41.	26.			11.
1130T	01-2696	F	J	78334	411	8.3	45	0.10	0.87	3.7	32.			25.	
1139U	01-2724	F	J	79046	441	8.9	46	0.098	0.87	3.6	32.			24.	
966T	03-1960	F	B	77012	439	10.3	47	0.097	1.0	3.6	37.			24.	
1007A	01-2194	M	E	77159	413	9.4	48	0.071	0.67	2.6	25.			18.	

IVE ALPHA RADIATION DOSE (GY)

9-30-91 WBC LUNG	TO DEATH WBC LUNG	TO DEATH REC. LUNG	DEATH DATE	DAYS TO 9-30 1991	DAYS TO DEATH	COMMENT
		40.	79277		210	D-PNEUMONITIS
		31.	79049		206	D-PNEUMONITIS
		60.	79296		249	D-PNEUMONITIS
		17.	79190		347	E-PNEUMONITIS
		63.	77349		336	D-PNEUMONITIS
		59.	78198		487	D-PNEUMONITIS
		32.	79071		221	D-PNEUMONITIS
		41.	78216		561	E-PNEUMONITIS
		28.	79030		278	E-PNEUMONITIS
		66.	80224		522	E-PNEUMONITIS
		45.	78339		593	E-PNEUMONITIS
		40.	78194		399	D-PNEUMONITIS
		56.	79282		852	D-PNEUMONITIS
		34.	79236		387	E-PNEUMONITIS
		36.	79262		412	D-PNEUMONITIS
		59.	80349		1333	D-PNEUM. AND PUL.FIBROSIS;CARC.,LUNG
		54.	80291		904	D-PNEUMONITIS AND PULMONARY FIBROSIS
		50.	81108		793	D-PNEUMONITIS
		27.	78158		503	D-PNEUMONITIS
		47.	80123		737	E-PNEUMONITIS
		35.	79096		652	E-PNEUMONITIS
		30.	79074		728	D-PNEUMONITIS
		27.	81058		947	E-PNEUMONITIS AND PULMONARY FIBROSIS
		40.	80282		1266	D-PNEUMONITIS AND PULMONARY FIBROSIS
		5.6	79108		152	E-PNEUMONITIS
		32.	80027		345	D-PNEUMONITIS
	64.		87123		3204	D-CARCINOMA,LUNG
73.				4815		
	45.		81299		1684	D-PNEUM.AND PUL.FIB.;PUL. CARCINOMA
	43.		83146		1540	E-PNEUMONITIS AND PULMONARY FIBROSIS
	44.		82168		1981	E-PNEUM.AND PUL.FIB.;PUL.CARCINOMA
		27.	80295		1377	E PNEUMONITIS AND PULMONARY FIBROSIS
	39.		82277		1930	E-PUL. CARCINOMAS;PUL. FIBROSIS
	37.		82121		1787	D-PNEUM.AND PUL.FIB.;PUL.CARCINOMA
	36.		82003		1809	D-PUL.CARCINOMA;PNEUM.AND PUL.FIB.
		20.	80362		1438	D-PNEUM. AND PUL.FIBROSIS;CARC.,LUNG
		20.	80213		1134	D-PNEUMONITIS
	29.		83133		1528	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
	33.		82262		2013	D-PULMONARY CARCINOMA;PUL.FIBROSIS
	35.		84220		2666	E-BRONCHIOLOALVEOLAR CARCINOMA,LUNG
	31.		83252		2269	E-PUL.CARCINOMAS;PUL. FIBROSIS
	25.		83101		1713	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
		36.	81197		1086	E-PNEUMONITIS AND PULMONARY FIBROSIS
		11.	81197		973	D-CARC.,KIDNEY;PNEUM. AND PUL. FIB.
	25.		83287		1779	E-PNEUMONITIS;BRONCHIOLOALVEOLAR CARC.
	24.		83350		1765	E-PNEUMONITIS AND PULMONARY FIBROSIS
	24.		81353		1802	D-PNEUM.AND PUL.FIB.;PUL.CARCINOMA
	18.		82274		1941	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.

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(1)

A.20 $^{239}PuO_2$ Monodisperse Aerosol (1.5 μm AMAD), Longevity Study (continued)

DOG IDENTIFICATION			INHALATION EXPOSURE				ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RADIATION TO 9-30-91	TO DEA
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	WBC LUNG	WBC LUNG
1129A	02-2682	M	K	78320	398	8.8	49	0.069	0.61	2.6	23.			24.
1132C	01-2684	M	K	78321	394	11.3	50	0.065	0.73	2.4	27.	150.		
1099C	01-2602	M	I	78214	451	10.5	51	0.060	0.63	2.2	23.			14.
1153T	02-2742	F	L	79066	395	8.3	52	0.057	0.47	2.1	17.			19.
1129B	02-2684	M	K	78321	398	10.7	53	0.056	0.60	2.1	22.	100.		
999A	02-2130	M	C	77110	394	7.8	54	0.051	0.40	1.9	15.			19.
1130C	01-2682	M	K	78320	397	9.0	55	0.048	0.43	1.8	16.			17.
972S	02-1960	F	B	77012	428	8.2	56	0.046	0.38	1.7	14.			13.
1022T	02-2208	F	F	77173	394	9.5	57	0.045	0.43	1.7	16.			16.
992T	01-2112	F	D	77075	405	7.0	58	0.043	0.30	1.6	11.			14.
1110S	01-2590	F	H	78207	409	9.0	59	0.040	0.36	1.5	13.			12.
1025D	02-2194	M	E	77159	367	10.7	60	0.039	0.42	1.4	16.			11.
1007B	03-2194	M	E	77159	413	11.3	61	0.035	0.40	1.3	15.			13.
978B	02-1970	M	A	77019	406	8.6	62	0.028	0.24	1.0	8.9			10.
1094B	01-2514	M	G	78116	372	12.3	63	0.027	0.33	1.0	12.			6.2
1113A	03-2600	M	I	78213	408	9.5	64	0.026	0.25	0.96	9.3			9.8
1017A	02-2192	M	E	77158	389	9.0	65	0.023	0.21	0.85	7.8			9.1
1096D	02-2512	M	G	78116	366	10.5	66	0.021	0.22	0.78	8.1			6.0
1134S	02-2694	F	J	78333	393	8.2	67	0.020	0.16	0.74	5.9		7.5	
970F	03-1970	M	A	77019	437	8.8	68	0.017	0.15	0.63	5.6			6.2
992D	01-2130	M	C	77110	440	10.4	69	0.017	0.18	0.63	6.7			4.9
1112U	01-2588	F	H	78206	401	9.1	70	0.016	0.15	0.59	5.6		6.4	
969U	02-1958	F	B	77012	431	9.7	71	0.015	0.15	0.55	5.6			5.5
1146T	02-2724	F	J	79046	402	8.8	72	0.015	0.13	0.55	4.8		5.7	
1014C	01-2192	M	E	77158	397	8.5	73	0.014	0.12	0.52	4.4			5.5
1010T	03-2208	F	F	77173	418	10.0	74	0.014	0.14	0.52	5.2	4.8		
1153S	01-2742	F	L	79066	395	8.9	75	0.012	0.11	0.44	4.1		4.7	
1092C	01-2512	M	G	78116	382	9.7	76	0.011	0.11	0.41	4.1			4.1
986S	02-2112	F	D	77075	431	8.1	77	0.011	0.087	0.41	3.2			3.9
960U	01-1960	F	B	77012	446	9.1	78	0.010	0.093	0.37	3.4			3.9
1110A	02-2600	M	I	78213	415	8.4	79	0.0095	0.080	0.35	3.0			3.6
970S	01-1958	F	B	77012	430	9.6	80	0.0076	0.073	0.28	2.7			2.9
988U	02-2110	F	D	77074	429	8.9	81	0.0070	0.062	0.26	2.3		2.8	
994B	02-2128	M	C	77109	434	10.0	82	0.0063	0.063	0.23	2.3		2.5	
1100A	01-2600	M	I	78213	446	9.6	83	0.0061	0.059	0.23	2.2		2.4	
1097A	02-2508	M	G	78115	361	9.0	84	0.0061	0.055	0.23	2.0			2.4
1132D	02-2680	M	K	78319	392	9.7	85	0.0060	0.058	0.22	2.1		2.3	
1010W	02-2206	F	F	77172	417	10.4	86	0.0043	0.045	0.16	1.7		1.7	
1130S	01-2694	F	J	78333	410	8.3	87	0.0040	0.033	0.15	1.2			[illegible].5
972D	02-1968	M	A	77018	434	8.5	88	0.0040	0.034	0.15	1.3			1.6
1154S	02-2740	F	L	79065	388	9.0	89	0.0034	0.031	0.13	1.1		1.3	
1149T	01-2740	F	L	79065	411	7.5	90	0.0033	0.025	0.12	0.92		1.3	
971C	01-1968	M	A	77018	435	8.2	91	0.0024	0.020	0.089	0.74		0.98	
1131B	01-2680	M	K	78319	395	11.0	92	0.0023	0.025	0.085	0.92		0.88	
988S	01-2110	F	D	77074	429	9.5	93	0.0022	0.021	0.081	0.78			0.81
997A	01-2128	M	C	77109	414	10.6	94	0.0018	0.019	0.067	0.70			0.70
1095A	01-2508	M	G	78115	371	11.2	95	0.0013	0.015	0.048	0.55			0.51
1022V	01-2206	F	F	77172	393	9.6	96	0.0007	0.007	0.026	0.26			0.29
960T	02-1956	F	B	77007	441	9.4	C							
977A	01-1974	M	A	77024	415	11.7	C							
982S	03-2116	F	D	77080	446	10.0	C							
998A	01-2146	M	C	77117	416	10.5	C							
1010A	01-2198	M	E	77160	405	12.4	C							
1021S	01-2212	F	F	77174	396	9.3	C							
1093B	01-2510	M	G	78115	375	7.9	C							
1107S	01-2594	F	H	78208	417	9.0	C							
1109A	01-2605	M	I	78215	417	11.8	C							
1131A	01-2681	M	K	78319	395	12.2	C							
1136S	01-2695	F	J	78333	375	9.0	C							
1152S	01-2746	F	L	79065	396	9.2	C							

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
KBQ/KG REPRESENTS KILOBEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED RESPECTIVELY. PROMINENT FINDINGS ARE
(I) SIGNIFIES AN INCIDENTAL FINDING WHICH WAS NOT IMMEDIATELY LIFE-THEATENING.
CAUTION: THE RECONSTRUCTED INITIAL LUNG BURDENS, DENOTED BY (R) AND (REC) IN THIS TABLE MAY BE TOO HIGH BECAUSE OF CUR
THIS MAY LEAD TO CALCULATED ORGAN DOSES THAT ARE TOO HIGH. THIS PROBLEM IS ESPECIALLY IMPORTANT FOR DOGS I

(2)

CUMULATIVE ALPHA RADIATION DOSE (GY)

TO 9-30-91 WBC LUNG	TO DEATH WBC LUNG	TO DEATH REC. LUNG	DEATH DATE	DAYS TO 9-30 1991	DAYS TO DEATH	COMMENT
	24.		87085		3052	E-CARCINOMA,LUNG
		43.	80296		705	D-PNEUMONITIS AND PULMONARY FIBROSIS
	14.		83123		1735	D-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
	19.		88145		3366	E-CARCINOMA,LUNG
		37.	81087		862	D-PNEUMONITIS AND PULMONARY FIBROSIS
	19.		88358		4265	E-MALIGNANT MELANOMA,ORAL
	17.		88301		3633	E-PAPILLARY ADENOCARCINOMA,LUNG
	13.		82334		2148	D-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
	16.		87056		3535	E-CARCINOMA,LUNG
	14.		85221		3068	E-PNEUMONITIS AND PULMONARY FIBROSIS
	12.		85030		2330	D-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
	11.		84017		2414	E-ADENOCARCINOMA,LUNG
	13.		87285		3778	E-CARCINOMA,LUNG
	10.		88021		4019	E-CARCINOMA,LUNG
	6.2		82302		1647	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
	9.8		90059		4229	E-PAPILLARY ADENOCARCINOMA,LUNG
	9.1		90270		4860	E-OSTEOSARCOMA,STERNUM
	6.0		84265		2340	E-MULTIPLE CARCINOMAS,LUNG
7.5				4688		
	6.2		87312		3945	D-PNEUMONITIS, FIBROUS ADENOMA,LUNG;
	4.9		83234		2315	D-JEJUNUM, SMOOTH MUSCLE TUMOR
6.4				4815		
	5.5		86358		3633	E-HEMOLYTIC ANEMIA
5.7				4610		
	5.5		90115		4705	E-TRANSITIONAL CELL CARCINOMA,BLADDER
		2.3	80187		1109	D-NECROTIC PHARYNGITIS
4.7				4590		
	4.1		89033		3935	E-PAPILLARY ADENOCARCINOMA,LUNG
	3.9		87206		3783	D-CARCINOMA,LUNG
	3.9		89041		4412	E-ADENOCARCINOMA,OSTEOSARCOMA,LUNG
	3.6		90120		4290	E-LYMPHOSARCOMA
	2.9		89159		4530	E-PAPILLARY ADENOCARC.,MAM. GLAND
2.8				5312		
2.5				5277		
2.4				4808		
	2.4		91010		4643	E-CARCINOMA,LUNG
2.3				4702		
1.7				5214		
	1.5		91015		4430	D-PLEUROPNEUMONIA
	1.6		91214		5309	D-CARCINOMA,LUNG;CARCINOMA,LARYNX
1.3				4591		
1.3				4591		
0.98				5368		
0.88				4702		
	0.81		88012		3955	D-TRANSITIONAL CARCINOMA,BLADDER
	0.70		90262		4901	E-RENAL CELL CARCINOMA,KIDNEY
	0.51		90248		4516	E-HEPATOCELLULAR CARCINOMA,LIVER
	0.29		91027		4968	D-CARCINOMA,MAMMARY GLAND
				5379		
			88349		4342	E-CHRONIC INTERSTITIAL NEPHRITIS
			89200		4503	E-MALIGNANT MELANOMA,ORAL
				5269		
			91263		5216	E-ASTROCYTOMA
				5212		
			90173		4441	D-RENAL AMYLOIDOSIS
				4813		
				4806		
			88139		3472	E-OSTEOSARCOMA,BONE
				4688		
				4591		

TION EXPOSURE.
ILY. PROMINENT FINDINGS ARE INCLUDED.

MAY BE TOO HIGH BECAUSE OF CURRENT ANALYTICAL RADIOCHEMICAL PROBLEMS.
PECIALLY IMPORTANT FOR DOGS IN THE LOWER EXPOSURE LEVELS.

A.21 $^{239}PuO_2$ Monodisperse Aerosol (3.0 μm AMAD), Longevity Study

DOG IDENTIFICATION		INHALATION EXPOSURE					ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RADIATION [illegible] TO 9-30-91	TO DEA[illegible]
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	WBC LUNG	WBC LUNG
1122B	03-2620	M	K	78251	395	8.5	01	2.0	17.	74.	620.	540		
984A	02-2104	M	C	77068	426	11.3	02	1.4	15.	52.	570.	480		
1069A	03-2398	M	G	78018	431	11.6	03	1.4	16.	52.	590.	490		
1004S	03-2170	F	D	77133	395	8.9	04	1.3	11.	48.	420.	390		
1152V	03-2738	F	L	79061	392	9.7	05	1.2	12.	44.	440.	330		
981T	03-2078	F	B	77033	403	11.1	06	1.1	13.	41.	470.	420		
1138T	03-2722	F	J	79039	440	6.7	07	0.88	5.9	33.	220.	110		
997D	03-2144	M	E	77117	422	8.4	08	0.77	6.5	28.	240.	240		
1001A	02-2144	M	E	77117	389	10.4	09	0.70	7.3	26.	270.	110		
1100D	03-2554	M	I	78159	392	10.7	10	0.68	7.3	25.	270.	250		
1069B	02-2398	M	G	78018	431	11.3	11	0.58	6.5	21.	240.	220		
1117D	02-2620	M	K	78251	429	9.2	12	0.58	5.3	21.	200.	280		
1034S	03-2234	F	F	77215	401	7.7	13	0.56	4.3	21.	160.	220		
1099A	02-2554	M	I	78159	396	11.2	14	0.56	6.3	21.	230.	93		
1124B	01-2620	M	K	78251	382	11.2	15	0.56	6.3	21.	230.	240		
1101U	03-2552	F	H	78158	388	10.5	16	0.55	5.8	20.	210.	200		
977T	02-2078	F	B	77033	428	7.9	17	0.52	4.1	19.	150.	100		
980A	01-2104	M	C	77068	443	10.5	18	0.51	5.4	19.	200.	200		
977U	01-2078	F	B	77033	428	10.5	19	0.47	4.9	17.	180.	140		
1149S	02-2738	F	L	79061	407	8.8	20	0.42	3.7	16.	140.			85.
964A	01-1950	M	A	77005	436	9.9	21	0.39	3.9	14.	140.	160		
1137U	02-2722	F	J	79039	440	10.4	22	0.36	3.7	13.	140.	160		
1000B	01-2144	M	E	77117	459	10.9	23	0.35	3.8	13.	140.	190		
1105T	02-2552	F	H	78158	377	10.1	24	0.35	3.5	13.	130.	100		
1007S	01-2170	F	D	77133	387	7.5	25	0.33	2.5	12.	93.	78		
1071A	01-2398	M	G	78018	427	10.4	26	0.30	3.1	11.	110.			62.
1029S	01-2234	F	F	77215	417	10.5	27	0.28	2.9	10.	110.	93		
989A	03-2104	M	C	77068	417	9.9	28	0.28	2.8	10.	100.			62.
980V	01-2076	F	B	77032	407	9.0	29	0.27	2.4	10.	89.	81		
1105A	01-2554	M	I	78159	378	10.3	30	0.25	2.6	9.3	96.	100		
1101T	01-2552	F	H	78158	388	8.4	31	0.25	2.1	9.3	78.	74		
1137T	01-2722	F	J	79039	440	10.0	32	0.24	2.4	8.9	89.			50.
1147U	01-2738	F	L	79061	409	9.3	33	0.24	2.2	8.9	81.			45.
1005S	02-2170	F	D	77133	391	8.8	34	0.24	2.1	8.9	78.			59.
1117C	03-2618	M	K	78250	428	11.0	35	0.16	1.8	5.9	67.			42.
1070A	03-2396	M	G	78017	427	10.5	36	0.16	1.7	5.9	63.			37.
1023U	02-2234	F	F	77215	436	7.9	37	0.14	1.1	5.2	41.			36.
1008T	01-2166	F	D	77132	383	7.9	38	0.12	0.93	4.4	34.			38.
963A	02-1950	M	A	77005	437	12.1	39	0.12	1.4	4.4	52.			27.
1152U	03-2736	F	L	79060	391	9.4	40	0.11	1.0	4.1	37.			33.
1139T	03-2720	F	J	79038	433	9.8	41	0.11	1.1	4.1	41.			25.
1104A	02-2556	M	I	78160	381	11.0	42	0.11	1.2	4.1	44.			29.
1005B	03-2142	M	E	77118	376	8.9	43	0.10	0.93	3.7	34.			39.
1097D	03-2556	M	I	78160	406	9.9	44	0.10	1.0	3.7	37.			23.
1070B	02-2396	M	G	78017	427	11.5	45	0.096	1.1	3.6	41.			32.
1121B	02-2618	M	K	78250	407	9.2	46	0.087	0.80	3.2	30.			26.
1023V	03-2232	F	F	77214	435	8.7	47	0.084	0.73	3.1	27.			25.
986A	01-2102	M	C	77067	423	10.8	48	0.074	0.80	2.7	30.			22.
1106S	03-2550	F	H	78157	374	10.2	49	0.072	0.73	2.7	27.			21.

CUMULATIVE ALPHA RADIATION DOSE (GY)

TO 9-30-91	TO DEATH			DAYS		
WBC LUNG	WBC LUNG	REC. LUNG	DEATH DATE	TO 9-30 1991	TO DEATH	COMMENT
		38	78356		105	E-PNEUMONITIS
		28	77184		116	D-PNEUMONITIS
		63	78306		288	D-PNEUMONITIS
		53	77363		230	D-PNEUMONITIS
		71	80123		427	E-PNEUMONITIS
		51	77289		256	D-PNEUMONITIS
		48	80305		631	E-PNEUMONITIS AND PULMONARY FIBROSIS
		76	78306		554	D-PNEUMONITIS
		31	79023		636	E-PNEUMONITIS
		54	79265		471	D-PNEUMONITIS
		68	80042		754	D-PNEUMONITIS
		79	80046		525	E-PNEUMONITIS
		69	78356		506	D-PNEUMONITIS
		38	81161		1098	E-PNEUMONITIS AND PULMONARY FIBROSIS
		49	79340		454	E-PNEUMONITIS
		64	80155		727	E-PNEUMONITIS
		35	78257		589	E-PNEUMONITIS
		59	79004		666	D-PNEUMONITIS
		40	78286		618	E-PNEUMONITIS
	85.		82320		1355	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
		53	78342		702	E-PNEUMONITIS
		65	81313		1005	E-PNEUMONITIS AND PULMONARY FIBROSIS
		56	80130		1108	E-CARCINOMA,LUNG
		45	81077		1015	E-PNEUMONITIS AND PULMONARY FIBROSIS
		36	79184		781	D-PNEUMONITIS
	62.		81356		1434	E-PULMONARY FIBROSIS;PUL.CARCINOMA
		50	79218		733	D-PNEUMONITIS
	62.		81132		1525	E-PNEUM. AND PUL. FIBROSIS;CARC.,LUNG
		32	79178		876	D-PNEUMONITIS
		43	81118		1055	E-PNEUMONITIS AND PULMONARY FIBROSIS
		39	81105		1043	E-PNEUMONITIS AND PULMONARY FIBROSIS
	50.		82365		1422	D-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
	45.		82222		1257	E-PNEUMONITIS AND PULMONARY FIBROSIS
	59.		82151		1844	D-PNEUM.AND PUL.FIB.;PUL.CARCINOMA
	42.		83349		1925	E-ADENOCARCINOMA,LUNG
	37.		82204		1648	E-PNEUM.AND PUL.FIB.;PUL.CARCINOMA
	36.		83011		1987	E-PULMONARY FIBROSIS;PUL. CARCINOMA
	38.		85110		2900	D-PNEUM. AND PUL. FIBROSIS;CARC.,LUNG
	27.		81160		1636	D-PNEUM. AND PUL. FIBROSIS;CARC.,LUNG
	33.		86301		2798	E-CARCINOMA,LUNG
	25.		83138		1561	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
	29.		84065		2096	E-BRONCHIOLOALVEOLAR CARCINOMA
	39.		86328		3497	E-CARCINOMA,LUNG
	23.		82357		1658	E-PNEUMONITIS AND PULMONARY FIBROSIS
	32.		86280		3185	E-CARCINOMA,LUNG
	26.		85143		2450	E-CARCINOMA,LUNG
	25.		84109		2451	E-ADENOCARCINOMA,LUNG
	22.		84038		2527	E-B.A. COMBINED CARCINOMAS,LUNG
	21.		84353		2387	E-CARCINOMA,LUNG

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A.21 $^{239}PuO_2$ Monodisperse Aerosol (3.0 μm AMAD), Longevity Study (continued)

DOG IDENTIFICATION		INHALATION EXPOSURE					ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RADIATIC TO 9-30-91	TO
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	WBC LUNG	WBC LUNG
999B	02-2142	M	E	77116	400	9.2	50	0.062	0.57	2.3	21.			23.
966A	02-1948	M	A	77004	431	11.1	51	0.058	0.64	2.1	24.			13.
1160V	02-2736	F	L	79060	365	9.8	52	0.054	0.53	2.0	20.			17.
1160S	01-2736	F	L	79060	365	9.3	53	0.053	0.49	2.0	18.			18.
980U	03-2076	F	B	77032	408	11.9	54	0.040	0.47	1.5	17.			13.
1139S	02-2720	F	J	79038	433	10.6	55	0.038	0.40	1.4	15.		15.	
988B	03-2102	M	C	77067	422	12.5	56	0.038	0.47	1.4	17.			13.
981S	02-2076	F	B	77032	403	10.2	57	0.038	0.39	1.4	14.			15.
1072B	01-2396	M	G	78017	425	11.4	58	0.034	0.39	1.3	14.			12.
1101A	01-2556	M	I	78160	390	10.6	59	0.030	0.32	1.1	12.			10.
1005U	03-2166	F	D	77132	390	9.3	60	0.029	0.27	1.1	10.			9.2
1099S	02-2550	F	H	78157	394	7.8	61	0.029	0.23	1.1	8.5			8.6
965A	03-1950	M	A	77005	436	12.3	62	0.029	0.36	1.1	13.			11.
1121C	01-2618	M	K	78250	401	10.4	63	0.026	0.27	0.96	10.			9.5
960A	03-1948	M	A	77004	438	10.0	64	0.025	0.25	0.92	9.3			9.0
1034T	01-2232	F	F	77214	400	6.4	65	0.023	0.15	0.85	5.6			8.3
1096T	01-2550	F	H	78157	407	9.8	66	0.019	0.19	0.70	7.0		7.6	
982A	02-2102	M	C	77067	437	10.5	67	0.018	0.19	0.67	7.0			6.7
1138S	01-2720	F	J	79038	439	7.6	68	0.014	0.11	0.52	4.1			5.6
994D	01-2142	M	E	77116	441	10.9	69	0.012	0.13	0.44	4.8			4.8
963B	01-1948	M	A	77004	436	11.7	70	0.011	0.13	0.41	4.8			4.3
1009S	02-2166	F	D	77132	380	10.6	71	0.010	0.11	0.37	4.1			3.7
1033U	02-2232	F	F	77214	403	8.5	72	0.0060	0.053	0.22	2.0			2.4
961D	01-1956	M	A	77007	448	11.6	C							
975S	01-2084	F	B	77035	433	7.4	C							
988D	01-2116	M	C	77080	435	10.0	C							
994C	01-2146	M	E	77117	442	12.7	C							
999T	01-2168	F	D	77130	414	8.4	C							
1033S	01-2240	F	F	77231	419	9.6	C							
1072C	01-2400	M	G	78019	427	10.5	C							
1104T	01-2558	F	H	78157	378	7.0	C							
1100C	01-2559	M	I	78158	391	10.6	C							
1122C	01-2622	M	K	78251	395	9.7	C							
1129U	01-2547	F	J	78352	407	8.7	C							
1152T	01-2739	F	L	79060	391	10.0	C							

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
KBQ/KG REPRESENTS KILOBEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED RESPECTIVELY. PROMINENT FINDINGS ARE
(I) SIGNIFIES AN INCIDENTAL FINDING WHICH WAS NOT IMMEDIATELY LIFE-THEATENING.
CAUTION: THE RECONSTRUCTED INITIAL LUNG BURDENS, DENOTED BY (R) AND (REC) IN THIS TABLE MAY BE TOO HIGH BECAUSE OF CUR
THIS MAY LEAD TO CALCULATED ORGAN DOSES THAT ARE TOO HIGH. THIS PROBLEM IS ESPECIALLY IMPORTANT FOR DOGS I

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CUMULATIVE ALPHA RADIATION DOSE (GY)

TO 9-30-91 WBC LUNG	TO DEATH WBC LUNG	TO DEATH REC. LUNG	DEATH DATE	DAYS TO 9-30 1991	DAYS TO DEATH	COMMENT
	23.		88228		4129	E-MALIGNANT MIXED TUMOR,LUNG
	13.		81121		1578	E-PNEUM. AND PUL. FIBROSIS;CARC.,LUNG
	17.		87093		2955	D-CARCINOMA,LUNG
	18.		88063		3290	E-CARCINOMA,LUNG
	13.		84347		2871	E-SQUAMOUS CELL CARCINOMA,MOUTH
15.				4618		
	13.		87041		3626	E-CARCINOMA,LUNG
	15.		89110		4461	E-ADENOSQUAMOUS CARCINOMA,LUNG
	12.		87084		3354	E-CARCINOMA,LUNG
	10.		87194		3321	E-CARCINOMA,LUNG
	9.2		85030		2820	E-CARCINOMA,LUNG
	8.6		85029		2429	D-CARCINOMA,LUNG
	11.		90046		4789	E-PAPILLARY ADENOCARCINOMA,LUNG
	9.5		89194		3962	E-PAPILLARY ADENOCARCINOMA,LUNG
	9.0		87118		3766	E-CARCINOMA,LUNG
	8.8		89136		4355	E-HEMANGIOSARCOMA,LIVER; CARC.,LUNG
7.6				4864		
	6.7		88195		4145	E-CARCINOMA,LUNG
	5.6		91052		4397	E-CONGESTIVE HEART FAILURE
	4.8		89143		4410	E-PAPILLARY ADENOCARCINOMA,LUNG
	4.3		91118		5227	D-CONGESTIVE HEART FAILURE;CARCINOMA,LUNG
	3.7		87140		3660	E-CARCINOMA,LUNG
	2.4		90002		4536	D-ADENOCARCINOMA,PANCREAS
			89097		4473	E-SQUAMOUS CELL CARCINOMA,TONSIL
			89219		4567	E-TRANSITIONAL CELL CARCINOMA,BLADDER
				5306		
			89321		4587	E-NEPHROBLASTOMA,KIDNEY
			90353		4971	D-MELANOMA,EYE
				5155		
			83143		1950	D-CONGESTIVE HEART FAILURE
				4864		
				4863		
				4770		
			88181		3481	E-OSTEOARTHRITIS,BONE
				4596		

N EXPOSURE.
. PROMINENT FINDINGS ARE INCLUDED.

BE TOO HIGH BECAUSE OF CURRENT ANALYTICAL RADIOCHEMICAL PROBLEMS.
IALLY IMPORTANT FOR DOGS IN THE LOWER EXPOSURE LEVELS.

(2)

A.22 $^{239}PuO_2$ Monodisperse Aerosol (1.5 μm AMAD), Immature Longevity Study

DOG IDENTIFICATION			INHALATION EXPOSURE				ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RADIATION DOSE (		
													TO 9-30-91	TO DEATH	
					AGE	WT							WBC	WBC	REC.
TATTOO	AN-EXPT	SEX	BLOCK	DATE	DAYS	KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	LUNG	LUNG	LUNG
1350A	01-3204	M	E	81296	104	2.4	01	0.79	1.9	29.	70.	21.			13.
1380V	03-3408	F	L	82266	96	3.9	02	0.74	2.9	27.	110.	130.			84.
1379A	01-3408	M	I	82266	96	4.8	03	0.69	3.3	26.	120.	56.			24.
1331S	02-3122	F	D	81225	97	2.8	04	0.64	1.8	24.	67.	12.			0.62
1379T	02-3408	F	J	82266	96	4.7	05	0.57	2.7	21.	100.	84.			36.
1389A	01-3454	M	K	83060	80	3.9	06	0.54	2.1	20.	78.	33.			18.
1367S	01-3314	F	H	82091	89	3.3	07	0.55	1.8	20.	67.	30.			17.
1366C	01-3312	M	G	82090	89	3.1	08	0.55	1.7	20.	63.	63.			36.
1331A	01-3122	M	C	81225	97	4.1	09	0.51	2.1	19.	78.	34.			16.
1340T	01-3140	F	F	81246	84	2.9	10	0.32	0.90	12.	33.		24.		
1377T	03-3398	F	J	82244	100	3.6	11	0.28	0.99	10.	37.	27.			15.
1365S	01-3310	F	H	82089	90	3.5	12	0.28	0.96	10.	36.	26.			15.
1351S	01-3216	F	F	81321	95	2.6	13	0.28	0.74	10.	27.	23.			15.
1362A	01-3300	M	G	82082	99	4.5	14	0.27	0.12	10.	4.4		3.3		
1350C	02-3204	M	E	81296	104	2.5	15	0.24	0.59	8.9	22.	14.			8.7
1217S	02-2856	F	B	79228	101	3.9	16	0.22	0.86	8.1	32.	41.			22.
1331U	01-3124	F	D	81226	98	2.8	17	0.21	0.60	7.8	22.			19.	
1390S	02-3454	F	L	83060	80	3.1	18	0.21	0.66	7.8	24.		18.		
1378B	04-3398	M	I	82244	97	4.4	19	0.19	0.83	7.0	31.	24.			7.0
1337T	01-3130	F	D	81238	88	3.3	20	0.17	0.56	6.3	21.		18.		
1336D	03-3130	M	E	81238	88	3.6	21	0.17	0.60	6.3	22.		18.		
1215A	01-2842	M	A	79220	100	5.2	22	0.16	0.82	5.9	30.	32.			17.
1366A	02-3310	M	G	82089	88	3.9	23	0.16	0.61	5.9	23.			15.	
1337U	02-3130	F	F	81238	88	3.0	24	0.16	0.46	5.9	17.			17.	
1220B	02-2844	M	A	79221	84	2.4	25	0.16	0.39	5.9	14.			10.	
1364S	01-3304	F	H	82084	99	4.5	26	0.13	0.59	4.8	22.			14.	
1387B	01-3442	M	K	82351	88	3.9	27	0.13	0.51	4.8	19.			12.	
1365A	02-3304	M	G	82084	85	3.7	28	0.13	0.49	4.8	18.			11.	
1377S	01-3390	F	J	82224	80	3.3	29	0.12	0.38	4.4	14.			9.4	
1377A	02-3390	M	I	82224	80	3.4	30	0.10	0.35	3.7	13.		8.2		
1384B	01-3418	M	K	82287	83	3.5	31	0.094	0.33	3.5	12.		8.4		
1384S	02-3418	F	L	82287	83	2.8	32	0.089	0.25	3.3	9.3			6.6	
1222T	02-2852	F	B	79227	79	1.9	33	0.079	0.15	2.9	5.6	16.			10.
1376A	01-33[illegible]	M	I	82223	87	2.2	34	0.074	0.16	2.7	5.9		5.5		
1339A	01-3132	M	E	81239	82	3.6	35	0.072	0.26	2.7	9.6		6.1		
1324T	01-3098	F	O	81174	98	5.3	36	0.069	0.39	2.6	14.			9.5	
1376T	02-3386	F	J	82223	87	2.2	37	0.068	0.15	2.5	5.6		6.0		
1363S	02-3302	F	H	82083	100	3.3	38	0.067	0.22	2.5	8.1		6.9		
1220T	01-2856	F	B	79228	91	2.5	39	0.065	0.16	2.4	5.9			5.4	
1364A	01-3302	M	G	82083	98	3.9	40	0.056	0.22	2.1	8.1		6.2		
1334D	02-3126	M	E	81231	95	2.2	41	0.056	0.12	2.1	4.4		3.5		
1222S	03-2852	F	B	79227	79	1.6	42	0.054	0.083	2.0	3.1		2.9		
1217A	01-2844	M	A	79221	94	4.8	43	0.052	0.25	1.9	9.3			6.1	
1387A	02-3442	M	K	82351	88	4.5	44	0.053	0.24	2.0	8.9			5.2	
1387S	03-3442	F	L	82351	88	3.0	45	0.047	0.14	1.7	5.2		4.1		
1384A	02-3416	M	K	82286	82	3.7	46	0.043	0.16	1.6	5.9		4.4		
1382S	01-3416	F	L	82286	92	4.1	47	0.039	0.16	1.4	5.9		4.8		
1338T	02-3132	F	F	81239	84	2.5	48	0.039	0.095	1.4	3.5		3.3		
1334B	01-3126	M	C	81231	95	3.1	49	0.035	0.11	1.3	4.1		2.6		

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ATIVE ALPHA RADIATION DOSE (GY)

0 9-30-91	TO DEATH			DAYS		
WBC LUNG	WBC LUNG	REC. LUNG	DEATH DATE	TO 9-30 1991	TO DEATH	COMMENT
		13.	87014		1909	E-CARCINOMA,LUNG
		84.	88012		1937	E-CARCINOMA,LUNG
		24.	87103		1663	D-CARCINOMA,LUNG
		0.62	81271		46	D-PARVOVIRUS INFECTION
		36.	86311		1506	E-CARCINOMA,LUNG
		18.	86316		1352	D-CARCINOMA,LUNG
		17.	86210		1580	E-CARCINOMA,LUNG
		36.	86051		1422	D-PNEUMONITIS; CARCINOMA,LUNG
		16.	86010		1611	D-PNEUMONITIS; CARCINOMA,LUNG
24.				3679		
		15.	86169		1386	E-PNEUMONITIS; CARCINOMA,LUNG
		15.	87210		1947	E-CARCINOMA,LUNG
		15.	87055		1925	E-CARCINOMA,LUNG
3.3				3478		
		8.7	86322		1852	E-ACCIDENTAL DEATH
		22.	84102		1700	E-RAD. PNEUM.;B.A. CARCINOMA,LUNG
	19.		88166		2496	E-CARCINOMA,LUNG
18.				3135		
		7.0	84253		739	D-HEMORRHAGIC ENTERITIS
18.				3687		
18.				3687		
		17.	85354		2326	E-CARCINOMA,LUNG
	15.		89249		2717	E-PULMONARY CARCINOMA,MULTIPLE
	17.		91235		3649	E-CARCINOMA,LUNG
	10.		87316		3017	E-CARCINOMA,LUNG
	14.		87239		1981	E-CARCINOMA,LUNG
	12.		89088		2294	E-ADENOSQUAMOUS CARCINOMA,LUNG
	11.		88200		2307	E-CARCINOMA,LUNG
	9.4		88251		2218	D-PNEUMONITIS/FIBROSIS; CARC.,LUNG
8.2				3336		
8.4				3273		
	6.6		88286		2190	E-ASTROCYTOMA,BRAIN
		10.	87078		2773	E-CARCINOMA,LUNG
5.5				3337		
6.1				3686		
	9.5		91036		3514	E-CARCINOMA,LUNG
6.0				3337		
6.9				3477		
	5.4		87301		2995	E-CARCINOMA,LUNG
6.2				3477		
3.5				3694		
2.9				4429		
	6.1		91023		4185	D-CARCINOMA,LUNG
	5.2		90058		2629	E-ADENOCARCINOMA, LUNG
4.1				3209		
4.4				3274		
4.8				3274		
3.3				3686		
2.6				3694		

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A.22 $^{239}PuO_2$ Monodisperse Aerosol (1.5 μm AMAD), Immature Longevity Study (continued)

DOG IDENTIFICATION			INHALATION EXPOSURE				ILB (WBC)					ILB (R)	CUMULATIVE AL TO 9-30-9
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	WBC LUNG
1367B	01-3320	M	I	82097	95	4.7	50	0.030	0.14	1.1	5.2		3.4
1368T	02-3320	F	J	82097	88	2.7	51	0.026	0.070	0.96	2.6		
1215B	03-2842	M	A	79220	100	4.6	52	0.024	0.11	0.89	4.1	11.	
1331C	02-3124	M	C	81226	98	4.0	53	0.024	0.093	0.89	3.4	12.	
1341S	02-3140	F	F	81246	84	2.6	54	0.024	0.062	0.89	2.3		2.4
1220D	02-2842	M	A	79220	83	2.2	55	0.023	0.050	0.85	1.9		1.5
1320S	01-3068	F	D	81128	90	3.8	56	0.021	0.080	0.78	3.0		2.4
1320A	01-3066	M	C	81127	89	4.6	57	0.020	0.093	0.74	3.4	43.	
1320C	02-3066	M	C	81127	89	4.1	58	0.020	0.080	0.74	3.0		
1220S	02-2848	F	B	79226	89	3.4	59	0.018	0.059	0.67	2.2		1.9
1362S	02-3300	F	H	82082	99	3.8	60	0.017	0.063	0.63	2.3		2.0
1381B	03-3414	M	K	82288	99	5.3	61	0.015	0.078	0.55	2.9		1.8
1381T	04-3414	F	L	82288	99	4.4	62	0.015	0.065	0.55	2.4		1.6
1373U	03-3384	F	J	82222	100	4.0	63	0.014	0.054	0.52	2.0		
1374A	02-3384	M	I	82222	94	3.0	64	0.014	0.043	0.52	1.6		1.1
1340A	01-3138	M	E	81245	83	3.8	65	0.013	0.049	0.48	1.8		1.2
1221T	01-2864	F	B	79234	95	1.8	66	0.013	0.023	0.48	0.85		0.87
1373T	01-3384	F	H	82222	100	4.2	67	0.012	0.051	0.44	1.9		1.4
1335A	01-3128	M	C	81232	83	3.4	68	0.0094	0.032	0.35	1.2		0.80
1318B	01-3054	M	C	81100	96	3.5	69	0.0064	0.022	0.24	0.81		0.58
1352C	01-3222	M	G	81338	97	4.0	70	0.0063	0.025	0.23	0.92		0.59
1340S	02-3138	F	F	81245	83	2.6	71	0.0058	0.015	0.21	0.55		0.45
1221C	03-2840	M	A	79219	80	2.4	72	0.0054	0.013	0.20	0.48	5.2	
1334S	03-3126	F	F	81231	92	3.7	73	0.0049	0.018	0.18	0.67		0.63
1377B	01-3398	M	I	82244	100	4.4	74	0.0045	0.020	0.17	0.74		0.49
1357S	02-3228	F	H	82008	96	3.2	75	0.0034	0.011	0.13	0.41		
1378S	02-3398	F	J	82244	97	4.2	76	0.0029	0.012	0.11	0.44		0.30
1386A	01-3432	M	K	82323	94	4.3	77	0.0026	0.011	0.096	0.41		0.28
1386S	02-3432	F	L	82323	94	3.5	78	0.0025	0.0088	0.093	0.33		0.31
1357B	01-3228	M	G	82008	96	4.4	79	0.0025	0.011	0.093	0.41		0.31
1342A	01-3160	M	E	81265	97	3.3	80	0.0021	0.0070	0.078	0.26		0.20
1223S	03-2848	F	B	79226	78	2.7	81	0.0021	0.0057	0.078	0.21		0.14
1217C	02-2840	M	A	79219	92	4.4	82	0.0012	0.0051	0.044	0.19		0.14
1214B	01-2840	M	A	79219	100	6.0	83	0.00095	0.0057	0.035	0.21		0.11
1335T	02-3128	F	D	81232	83	2.9	84	0.00093	0.0027	0.034	0.10		0.076
1381S	02-3414	F	L	82288	99	3.9	85	0.00082	0.0032	0.030	0.12		0.084
1381A	01-3414	M	K	82288	99	5.7	86	0.00060	0.0034	0.022	0.13		0.073
1339B	01-3134	M	E	81243	86	3.0	87	0.00058	0.0017	0.021	0.063		0.043
1317U	02-3052	F	D	81099	99	3.6	88	0.00056	0.0020	0.021	0.074		
1319S	03-3052	F	D	81009	94	4.1	89	0.00054	0.0022	0.020	0.081		0.060
1355A	01-3224	M	G	81356	91	5.0	90	0.00040	0.0020	0.015	0.074		0.046
1317A	01-3052	M	C	81099	98	3.9	91	0.00036	0.0014	0.013	0.052		
1367A	01-3316	M	I	82092	90	4.8	92	0.00035	0.0017	0.013	0.063		
1355T	02-3224	F	H	81356	91	4.1	93	0.00032	0.0013	0.012	0.048		0.031
1338S	02-3134	F	F	81243	88	2.8	94	0.00031	0.00085	0.011	0.031		0.026
1217T	01-2848	F	B	79226	99	5.0	95	0.00030	0.0015	0.011	0.056		0.050
1368S	02-3316	F	J	82092	83	3.0	96	0.00025	0.00076	0.0093	0.023		0.023
1216B	02-2857	M	A	79228	108	5.2	C						
1223T	01-2875	F	B	79240	92	2.8	C						
1317S	01-3055	F	D	81100	99	3.3	C						
1318D	02-3055	M	C	81100	96	4.2	C						
1342T	01-3162	F	F	81268	100	3.1	C						
1345A	01-3163	M	E	81272	83	3.5	C						
1353A	01-3223	M	G	81342	97	2.5	C						
1358S	01-3264	F	H	82020	101	3.5	C						
1368D	01-3318	M	I	82097	83	3.7	C						
1376U	01-3388	F	J	82225	89	2.7	C						
1380W	02-3410	F	L	82267	97	3.8	C						
1386B	01-3433	M	K	82326	97	4.1	C						

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
KBQ/KG REPRESENTS KILOBEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED RESPECTIVELY. PROMINENT FIND-
(I) SIGNIFIES AN INCIDENTAL FINDING WHICH WAS NOT IMMEDIATELY LIFE-THEATENING.
CAUTION: THE RECONSTRUCTED INITIAL LUNG BURDENS, DENOTED BY (R) AND (REC) IN THIS TABLE MAY BE TOO HIGH BECAU
THIS MAY LEAD TO CALCULATED ORGAN DOSES THAT ARE TOO HIGH. THIS PROBLEM IS ESPECIALLY IMPORTANT F

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	ILB (R)	CUMULATIVE ALPHA RADIATION DOSE (GY) TO 9-30-91	TO DEATH			DAYS		
KBQ	KBQ	WBC LUNG	WBC LUNG	REC. LUNG	DEATH DATE	TO 9-30 1991	TO DEATH	COMMENT
5.2		3.4				3463		
2.6			2.2		90277		3102	D-CONGESTIVE HEART FAILURE
4.1	11.			4.9	83317		1558	D-HEMORRHAGIC ENTERITIS
3.4	12.			4.2	83246		750	D-HEMOLYTIC ANEMIA
2.3		2.4				3679		
1.9		1.5				4436		
3.0		2.4				3797		
3.4	43.			23.	86135		1834	E-CARCINOMA,LUNG
3.0			1.7		87209		2273	E-CARCINOMA,LUNG
2.2		1.9				4430		
2.3		2.0				3478		
2.9		1.8				3272		
2.4		1.6				3272		
2.0			1.5		90159		2859	D-HISTIOCYTIC SARCOMA; ADENOCARCINOMA, LUNG
1.6		1.1				3338		
1.8		1.2				3680		
).85		0.87				4422		
1.9		1.4				3338		
1.2		0.80				3693		
).81		0.58				3825		
).92		0.59				3587		
).55		0.45				3680		
).48	5.2			2.1	81332		844	D-EPILEPSY
).67		0.63				3694		
).74		0.49				3316		
).41			0.12		83131		488	E-UNDETERMINED
).44		0.30				3316		
).41		0.28				3237		
).33		0.31				3237		
).41		0.31				3552		
).26		0.20				3660		
:.21		0.14				4430		
).19		0.14				4437		
).21		0.11				4437		
).10		0.076				3693		
).12		0.084				3272		
).13		0.073				3272		
).063		0.043				3682		
).074			0.058		91017		3570	E-CARCINOMA,NASAL CAVITY;CARCINOMA,LUNG
).081		0.060				3826		
).074		0.046				3569		
).052			0.030		86105		1832	E-NEUROFIBROSARCOMA,PERITONIUM
).063			0.038		91004		3199	E-FIBROSARCOMA,LIVER
).048		0.031				3569		
).031		0.026				3682		
).056		0.050				4430		
).028		0.023				3468		
					80113		250	D-ACUTE PULMONARY EDEMA
						4416		
						3825		
						3825		
						3657		
						3653		
						3583		
						3540		
						3463		
						3335		
						3293		
						3234		

:HT.
:IGHT.
:R INHALATION EXPOSURE.
:ESPECTIVELY. PROMINENT FINDINGS ARE INCLUDED.
:ATENING.
IS TABLE MAY BE TOO HIGH BECAUSE OF CURRENT ANALYTICAL RADIOCHEMICAL PROBLEMS.
.EM IS ESPECIALLY IMPORTANT FOR DOGS IN THE LOWER EXPOSURE LEVELS.

A.23 $^{239}PuO_2$ Monodisperse Aerosol (1.5 μm AMAD), Aged Longevity Study

DOG IDENTIFICATION			INHALATION EXPOSURE				ILB (WBC)					ILB (R)	CUMULATIVE ALPHA RADIATIO[N] TO DEATH
TATTOO	AN-EXPT	SEX	BLOCK	DATE	AGE DAYS	WT KG	RANK	UCI/KG	UCI	KBQ/KG	KBQ	KBQ	WBC LUNG
412C	02-2754	M	C	79101	3520	10.8	01	0.66	7.1	24.	260.		35.
503A	01-2878	M	E	79282	3256	12.9	02	0.53	6.9	20.	260.	280	
482S	02-2878	F	H	79282	3352	9.5	03	0.57	5.4	21.	200.	220	
606T	01-2954	F	L	80176	3068	9.8	04	0.52	5.1	19.	190.	96	
385B	01-2760	M	A	79115	3649	11.7	05	0.39	4.6	14.	170.		33.
637T	02-2954	F	L	80176	2942	9.8	06	0.40	3.9	15.	140.	120	
450S	04-2812	F	F	79144	3382	10.9	07	0.34	3.7	13.	140.	230	
637A	02-3344	M	I	82169	3666	11.7	08	0.32	3.8	12.	140.	340	
363T	01-2754	F	D	79101	3760	9.7	09	0.29	2.8	11.	100.	110	
351C	03-2752	M	C	79100	3784	10.4	10	0.26	2.7	9.6	100.	93	
729D	01-3348	M	K	82182	3304	8.8	11	0.24	2.1	8.9	78.	250	
519U	02-2928	F	J	80045	3295	11.0	12	0.23	2.5	8.5	93.	93	
693A	01-3344	M	G	82169	3443	10.8	13	0.23	2.5	8.5	93.	260	
492T	01-2880	F	H	79283	3317	9.8	14	0.22	2.3	8.1	85.	74	
389A	02-2812	M	A	79144	3665	12.9	15	0.19	2.4	7.0	89.	120	
360U	03-2812	F	B	79144	3812	9.9	16	0.17	1.7	6.3	63.		4.6
590S	01-2928	F	J	80045	3022	8.1	17	0.17	1.4	6.3	52.	41	
365S	03-2756	F	D	79102	3757	10.6	18	0.16	1.7	5.9	63.	100	
424T	01-2812	F	F	79144	3480	11.2	19	0.15	1.7	5.6	63.	100	
483S	03-2880	F	H	79283	3344	11.9	20	0.14	1.7	5.2	63.		13.
378S	03-2758	F	B	79114	3687	12.1	21	0.13	1.6	4.8	59.	63	
343U	02-2756	F	D	79102	3826	11.6	22	0.13	1.5	4.8	56.		7.6
723B	01-3342	M	G	82167	3301	9.9	23	0.12	1.2	4.4	44.	160	
638A	03-3342	M	K	82167	3661	9.5	24	0.12	1.1	4.4	41.	200	
682B	02-3342	M	I	82167	3482	11.0	25	0.10	1.1	3.7	41.	170	
480T	02-2814	F	F	79145	3215	8.8	26	0.11	0.98	4.1	36.	56	
503B	03-2878	M	E	79282	3256	12.9	27	0.10	1.3	3.7	48.	59	
346S	02-2758	F	B	79114	3829	11.7	28	0.10	1.2	3.7	44.	52	
627S	01-2956	F	L	80177	2973	8.8	29	0.10	0.87	3.7	32.		17.
466A	02-2880	M	E	79283	3411	10.4	30	0.092	0.96	3.4	36.	36	
359D	02-2752	M	C	79100	2768	7.8	31	0.083	0.65	3.1	24.	28	
387B	03-2814	M	A	79145	3676	11.6	32	0.075	0.87	2.8	32.	56	
375T	01-2756	F	D	79102	3679	10.6	33	0.073	0.78	2.7	29.	37	
595T	01-2930	F	J	80042	3154	9.9	34	0.066	0.65	2.4	24.	32	
692B	03-3340	M	K	82166	3443	8.2	35	0.068	0.56	2.5	21.	41	
785B	02-3340	M	I	82166	2986	9.1	36	0.066	0.60	2.4	22.	41	
681D	01-3340	M	G	82166	3486	10.1	37	0.062	0.63	2.3	23.	110	
378C	01-2752	M	C	79100	3673	10.8	38	0.047	0.51	1.7	19.	27	
370S	01-2758	F	B	79114	3710	8.1	39	0.048	0.39	1.8	14.		7.0
639S	02-2956	F	L	80177	2935	13.4	40	0.032	0.43	1.2	16.		7.6
536S	02-2930	F	J	80046	3263	11.7	41	0.034	0.40	1.3	15.	21	
719A	04-3342	M	K	82137	3321	12.5	42	0.027	0.34	1.0	13.	31	
467S	01-2814	F	F	79145	3265	12.3	43	0.024	0.30	0.89	11.	35	
484A	01-2882	M	E	79284	3345	11.5	44	0.026	0.30	0.96	11.	29	
719B	01-3338	M	G	82162	3316	10.5	45	0.022	0.23	0.81	8.5	27	
346B	01-2762	M	A	79116	3831	12.7	46	0.024	0.31	0.89	11.	19	
477S	02-2882	F	H	79284	3363	12.0	47	0.023	0.28	0.85	10.		4.5
731B	02-3338	M	I	82162	3272	6.7	48	0.013	0.09	0.48	3.3		2.9
361S	02-2765	F	D	79099	3357	12.7	C						
367A	01-2765	M	C	79099	3729	11.9	C						
373S	01-2757	F	B	79113	3694	7.5	C						
398C	02-2757	M	A	79113	3575	12.6	C						
459U	01-2815	F	F	79149	3319	10.5	C						
495S	02-2884	F	H	79285	3292	10.1	C						
510A	01-2884	M	E	79285	3208	9.5	C						
564T	01-2932	F	J	80046	3154	9.9	C						
625S	01-2952	F	L	80177	2977	9.9	C						
655B	02-3346	M	I	82168	3621	8.9	C						
713A	01-3346	M	G	82168	3370	10.4	C						
785A	03-3346	M	K	82168	3002	8.3	C						

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UCI/KG REPRESENTS MICROCURIES OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
KBQ/KG REPRESENTS KILOBEQUERELS OF RADIONUCLIDE PER KILOGRAM OF TOTAL BODY WEIGHT.
DOSE RATE AND CUMULATIVE DOSE ARE PRESENTED AS FUNCTIONS OF TIME IN DAYS AFTER INHALATION EXPOSURE.
COMMENT: D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED RESPECTIVELY. PROMINENT FINDINGS ARE IN[
(I) SIGNIFIES AN INCIDENTAL FINDING WHICH WAS NOT IMMEDIATELY LIFE-THEATENING.
CAUTION: THE RECONSTRUCTED INITIAL LUNG BURDENS, DENOTED BY (R) AND (REC) IN THIS TABLE MAY BE TOO HIGH BECAUSE OF CURREN[
THIS MAY LEAD TO CALCULATED ORGAN DOSES THAT ARE TOO HIGH. THIS PROBLEM IS ESPECIALLY IMPORTANT FOR DOGS IN T[

(2)

CUMULATIVE ALPHA RADIATION DOSE (GY)

TO DEATH				
WBC LUNG	REC. LUNG	DEATH DATE	DAYS TO DEATH	COMMENT
35.		80033	297	D-PNEUMONITIS
	23.	80121	204	D-PLEURITIS (NOCARDIA SP.)
	51.	81057	506	E-PNEUMONITIS AND PULMONARY FIBROSIS
	7.5	80317	141	E-CARCINOMA, MAMMARY GLAND
33.		80270	520	D-PNEUMONITIS
	35.	82126	681	E-PNEUMONITIS AND PULMONARY FIBROSIS
	29.	80059	280	E-PNEUMONITIS
	24.	82321	152	D-PNEUMONITIS AND PULMONARY FIBROSIS
	12.	79309	208	D-PNEUMONITIS
	26.	81100	731	D-PULMONARY FIBROSIS
	28.	83007	190	E-LYMPHOSARCOMA-LIVER
	26.	82116	802	E-PNEUMONITIS AND PULMONARY FIBROSIS
	20.	82316	147	E-PNEUMONITIS AND PULMONARY FIBROSIS
	20.	81199	647	D-PNEUMONITIS AND PULMONARY FIBROSIS
	21.	80271	494	E-PNEUMONITIS
4.6		79273	129	D-PNEUMONITIS
	18.	82322	1008	E-PNEUMONITIS AND PULMONARY FIBROSIS
	21.	80234	497	D-PNEUMONITIS
	23.	80358	579	E-PNEUMONITIS AND PULMONARY FIBROSIS
13.		81153	601	E-PNEUMONITIS AND PULMONARY FIBROSIS
	19.	82012	994	D-PERITONITIS
7.6		80070	333	D-PNEUMONITIS
	32.	83259	457	E-PNEUMONITIS AND PULMONARY FIBROSIS
	23.	83014	212	D-PNEUMONITIS AND PULMONARY FIBROSIS
	14.	82334	167	D-PNEUMONITIS AND PULMONARY FIBROSIS
	21.	81350	936	D-LYMPHOSARCOMA-DUODENUM
	16.	82113	927	E-PNEUMONITIS AND PULMONARY FIBROSIS
	16.	81361	978	D-PNEUMONITIS AND PULMONARY FIBROSIS
17.		84125	1409	E-PNEUMONITIS AND PULMONARY FIBROSIS
	15.	83080	1258	E-PNEUMONITIS AND PULMONARY FIBROSIS
	17.	83105	1466	E-PNEUMONITIS AND PULMONARY FIBROSIS
	18.	82061	1012	D-CARDIAC FAILURE
	12.	81249	878	E-PNEUMONITIS AND PULMONARY FIBROSIS
	13.	83067	1117	E-PNEUMONITIS AND PULMONARY FIBROSIS
	23.	86184	1479	D-ISLET CELL CARCINOMA,PANCREAS
	22.	86286	1581	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
	24.	83291	490	E-PNEUMONITIS AND PULMONARY FIBROSIS
	14.	84166	1892	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
7.0		82123	1105	D-ACCIDENTAL DEATH
7.6		88096	2841	E-CARCINOMA,LUNG
	8.2	83290	1340	E-CARCINOMA,TONSIL
	13.	87149	1808	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
	16.	84316	1997	D-THROMBOSIS,LUNG
	14.	85081	1989	E-PNEUM. AND PUL. FIBROSIS;PUL. CARC.
	10.	85179	1113	E-LIVER,DEGENERATION
	1.9	80004	253	E-MALIGNANT MELANOMA
4.5		84279	1821	E-PNEUMONITIS AND PULMONARY FIBROSIS
2.9		88153	2182	E-VISCERAL LYMPHOSARCOMA
		85087	2176	E-CARCINOMA,MOUTH
		85358	2447	E-ADENOCARCINOMA,LUNG
		83327	1675	E-ADENOCARCINOMA,MAMMARY
		83031	1379	E-TONSIL SQUAMOUS CELL CARCINOMA
		82342	1289	D-CARCINOMA,KIDNEY
		81139	585	D-ACCIDENTAL DEATH
		85225	2132	D-BRONCHOPNEUMONIA,LUNG
		85141	1922	E-MELONOMA,MOUTH
		86352	2369	D-CONGESTIVE HEART FAILURE
		85012	926	D-CHEMODECTOMA,MALIGNANT
		87051	1695	E-NEPHRITIS,KIDNEY
		88090	2099	E-CARCINOMA,BLADDER

EXPOSURE.
PROMINENT FINDINGS ARE INCLUDED.

E TOO HIGH BECAUSE OF CURRENT ANALYTICAL RADIOCHEMICAL PROBLEMS.
LLY IMPORTANT FOR DOGS IN THE LOWER EXPOSURE LEVELS.

A.24 $^{239}PuO_2$ Monodisperse Aerosol (0.75 μm AMAD), Repeated Exposure Study

DOG IDENTIFICATION			INHALATION EXPOSURE		FIRST EXPOSURE			TLB (WBC)					MAXIMUM ALPHA	A DO.
TATTOO	AN-EXPT	SEX	GROUP	BLOCK	DATE	AGE DAYS	WT KG	NCI/KG	NCI	KBQ/KG	KBQ	NUMBER OF EXPOSURES	DOSE RATE GY/DAY	TO ?
1028A	01-2244	M	I	A	77229	433	11.1	14	150	0.52	5.6	1	.0032	
1036A	02-2244	M	I	C	77229	406	11.7	7	80	0.26	3.0	1	.0016	
1025A	03-2244	M	I	C	77229	437	12.0	16	190	0.59	7.0	1	.0038	
1028B	04-2244	M	I	A	77229	433	9.0	9	80	0.33	3.0	1	.0021	
1044U	01-2266	F	I	B	77243	379	7.7	12	90	0.44	3.3	1	.0028	
1050B	02-2266	M	I	E	77243	368	10.8	17	180	0.63	6.7	1	.0040	
1040S	03-2266	F	I	B	77243	395	8.8	10	90	0.37	3.3	1	.0025	
1050A	04-2266	M	I	E	77243	368	11.2	10	110	0.37	4.1	1	.0024	
1055W	01-2292	F	I	D	77271	387	8.1	19	150	0.70	5.6	1	.0044	
1050S	02-2292	F	I	D	77271	396	9.4	15	140	0.56	5.2	1	.0036	
1051B	03-2292	M	I	G	77271	395	11.3	13	150	0.48	5.6	1	.0032	
1058B	04-2292	M	I	G	77271	369	10.0	15	150	0.56	5.6	1	.0036	
1061A	01-2318	M	I	I	77291	371	10.3	20	210	0.74	7.8	1	.0049	
1060S	02-2318	F	I	F	77291	384	10.3	17	170	0.63	6.3	1	.0040	
1055T	03-2318	F	I	F	77291	407	9.9	17	170	0.63	6.3	1	.0041	
1060B	04-2318	M	I	I	77291	384	9.9	13	130	0.48	4.8	1	.0031	
1063C	01-2348	M	I	K	77312	390	9.1	12	110	0.44	4.1	1	.0029	
1067B	02-2348	M	I	K	77312	371	8.4	12	100	0.44	3.7	1	.0029	
1061T	03-2348	F	I	H	77312	392	8.5	25	210	0.93	7.8	1	.0059	
1062S	04-2348	F	I	H	77312	391	8.9	19	170	0.70	6.3	1	.0046	
1077U	01-2388	F	I	L	78010	405	7.9	33	260	1.2	9.6	1	.0079	
1077V	02-2388	F	I	J	78010	405	8.0	26	210	0.96	7.8	1	.0063	
1073T	03-2388	F	I	L	78010	417	8.4	70	590	2.6	22.	1	.017	
1077S	04-2388	F	I	J	78010	405	8.4	25	210	0.93	7.8	1	.0060	
1027C	03-2246	M	II	A	77230	435	12.4	130	1500	5.0	54.	10	.018	
1040C	04-2246	M	II	C	77230	382	10.1	120	1300	4.4	47.	9	.018	
1036S	01-2268	F	II	B	77244	421	9.6	120	1200	4.3	46.	9	.016	
1045D	02-2268	M	II	E	77244	379	10.6	140	1500	5.0	55.	10	.018	
1055U	01-2294	F	II	D	77272	388	8.6	130	1200	4.7	43.	10	.018	
1051D	03-2294	M	II	G	77272	396	10.7	120	1200	4.3	46.	9	.017	
1062B	01-2320	M	II	I	77292	371	12.3	150	2000	5.6	75.	10	.021	
1049S	03-2320	F	II	F	77292	419	9.8	110	1200	4.1	45.	8	.017	
1061S	01-2350	F	II	H	77313	393	8.4	180	1600	6.8	58.	9	.027	
1064A	02-2350	M	II	K	77313	391	10.3	150	1500	5.4	54.	9	.021	
1070S	01-2390	F	II	L	78011	421	8.2	140	1300	5.3	49.	10	.023	
1069S	04-2390	F	II	J	78011	424	10.2	180	1800	6.7	67.	9	.028	
1037B	01-2248	M	III	C	77231	397	9.7	23	240	0.85	8.9	20	.0027	
1025B	02-2248	M	III	A	77231	439	10.7	21	220	0.78	8.3	18	.0024	
1027B	03-2248	M	III	A	77231	436	10.9	13	160	0.48	6.0	12	.0017	
1035A	04-2248	M	III	C	77231	410	8.5	24	210	0.89	7.9	19	.0026	
1041B	01-2272	M	III	E	77245	384	9.6	24	240	0.89	8.9	19	.0026	
1046B	02-2272	M	III	E	77245	378	7.2	25	200	0.93	7.5	16	.0027	
1035U	03-2272	F	III	B	77245	424	7.4	24	180	0.89	6.8	16	.0029	
1029U	04-2272	F	III	B	77245	446	8.4	27	220	1.0	8.1	18	.0030	
1054B	01-2296	M	III	G	77273	392	9.6	24	260	0.89	9.6	17	.0026	
1057A	02-2296	M	III	G	77273	371	10.1	30	330	1.1	12.	20	.0030	
1046T	03-2296	F	III	D	77273	406	7.3	11	85	0.41	3.1	2	.0024	
1051S	04-2296	F	III	D	77273	397	9.0	34	330	1.3	12.	19	.0035	
1051A	01-2322	M	III	I	77293	417	11.7	26	300	0.96	11.	18	.0027	

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UMBER OF XPOSURES	MAXIMUM ALPHA DOSE RATE GY/DAY	CUMULATIVE ALPHA RADIATION DOSE TO LUNG (GY) TO 9-30-91	TO DEATH	DEATH DATE	DAYS FROM FIRST EXPOSURE TO 9-30-91	DEATH	COMMENT
1	.0032		5.9	88284		4072	E-DISSEMINATED SARCOMA
1	.0016		2.9	88083		3871	E-PAPILLARY ADENOCARCINOMA, LUNG
1	.0038		6.3	87189		3612	E-CARCINOMA, LUNG
1	.0021		3.6	87317		3740	D-CONGESTIVE FAILURE, HEART
1	.0028		5.6	90290		4795	E-CARCINOMA,LUNG
1	.0040		8.1	90351		4856	E-MULTIPLE CARCINOMA,LUNG
1	.0025		2.5	82068		1651	D-IMMUNE HEMOLYTIC ANEMIA
1	.0024	4.7			5143		
1	.0044		9.1	91137		4979	E-CARCINOMA,LUNG
1	.0036		5.9	87183		3564	D-HEPATIC DEGENERATION;CARCINOMA,LUNG
1	.0032		5.5	88063		3809	D-PAPILLARY ADENOCARCINOMA, LUNG
1	.0036		6.8	89236		4348	E-ADENOSQUAMOUS CARCINOMA,LUNG
1	.0049		7.8	86343		3339	E-CARCINOMA, LUNG
1	.0040		6.4	87105		3466	E-MAMMARY GLAND ADENOCARCINOMA
1	.0041		6.8	87197		3558	E-CARCINOMA, LUNG
1	.0031		4.4	85084		2715	E-CARCINOMA, LUNG
1	.0029		5.1	88196		3901	D-MALIGNANT MIXED TUMOR, LUNG
1	.0029	5.7			5074		
1	.0059		9.6	87125		3465	E-CARCINOMA, LUNG
1	.0046		3.5	80247		1030	E-VERTEBRAL DISC HERNIATION
1	.0079		16.	90338		4711	E-CARCINOMA,LUNG
1	.0063		11.	89089		4097	E-PAPILLARY ADENOCARCINOMA,LUNG
1	.017		15.	83104		1920	E-PNEUMONITIS AND PUL. FIBROSIS;PUL. CARC.
1	.0060		9.3	86304		3216	D-CARCINOMA, LUNG
10	.018		24.	83047		2008	E-PNEUMONITIS AND PULMONARY FIBROSIS
9	.018		17.	82088		1684	E-PNEUMONITIS AND PULMONARY FIBROSIS
9	.016		16.	82041		1623	E-PNEUMONITIS AND PULMONARY FIBROSIS
10	.018		22.	82326		1908	D-PNEUMONITIS AND PUL. FIBROSIS;PUL. CARC.
10	.018		20.	83025		1944	E-PNEUMONITIS AND PULMONARY FIBROSIS
9	.017		20.	82341		1895	E-PNEUMONITIS AND PULMONARY FIBROSIS
10	.021		27.	83114		2013	D-PNEUMONITIS AND PULMONARY FIBROSIS
8	.017		14.	81293		1462	E-PNEUMONITIS AND PULMONARY FIBROSIS
9	.027		26.	82118		1631	E-PNEUMONITIS AND PULMONARY FIBROSIS
9	.021		24.	82316		1829	E-PNEUMONITIS AND PUL. FIBROSIS;PUL. CARC.
10	.023		30.	84194		2374	D-B.A. CARC.,LUNG;OSTEOSARCOMA,MANDIBLE
9	.028		31.	83077		1892	D-PULMONARY CARCINOMA
20	.0027		7.1	87222		3643	E-CARCINOMA, LUNG
18	.0024		6.3	87292		3713	E-SQUAMOUS CARCINOMA,LUNG
12	.0017		2.5	83165		2125	D-RUPTURED GALL BLADDER
19	.0026		8.1	89220		4372	E-PAPILLARY ADENOCARCINOMA,LUNG
19	.0026		6.4	86335		3377	E-CARCINOMA, LUNG
16	.0027		6.1	85356		3033	D-CARCINOMA,PITUITARY
16	.0029		8.0	88362		4134	E-TRANSITIONAL CELL CARCINOMA,BLADDER
18	.0030		7.4	87164		3571	E-CARCINOMA, LUNG
17	.0026		6.5	86191		3205	E-ADENOCARCINOMA,LUNG
20	.0030		11.	89030		4140	E-PAPILLARY ADENOCARCINOMA,LUNG
2	.0024		0.86	78272		364	D-ACCIDENTAL DEATH
19	.0035		10.	87238		3617	E-CARCINOMA, LUNG
18	.0027		8.0	87230		3589	E-CARCINOMA, LUNG

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A.24 $^{239}PuO_2$ Monodisperse Aerosol (0.75 μm AMAD), Repeated Exposure Study (continued)

DOG IDENTIFICATION			INHALATION EXPOSURE		FIRST EXPOSURE			TLB (WBC)				NUMBER OF	MAXIMUM ALPHA DOSE RATE	CUMULATIVE ALPHA RADIATI DOSE TO LUNG (	
TATTOO	AN-EXPT	SEX	GROUP	BLOCK	DATE	AGE DAYS	WT KG	NCI/KG	NCI	KBQ/KG	KBQ	EXPOSURES	GY/DAY	TO 9-30-91	TO D
1057S	02-2322	F	III	F	77293	391	8.5	24	210	0.89	7.9	18	.0027		6
1057T	03-2322	F	III	F	77293	391	9.4	26	230	0.96	8.3	20	.0029		8
1058C	04-2322	M	III	I	77293	391	10.3	19	210	0.70	7.8	20	.0021		6
1055S	01-2352	F	III	H	77314	430	8.9	38	350	1.4	13.	19	.0037		11
1066A	02-2352	M	III	K	77314	378	9.0	32	290	1.2	11.	20	.0031		11
1065B	03-2352	M	III	K	77314	391	10.1	26	270	0.96	10.	19	.0026		8
1067T	04-2352	F	III	H	77314	373	8.9	32	300	1.2	11.	20	.0031		11
1071S	01-2392	F	III	J	78012	421	8.6	23	210	0.85	7.9	19	.0026		7
1070U	02-2392	F	III	J	78012	422	9.7	17	170	0.63	6.4	14	.0022		3
1073U	03-2392	F	III	L	78012	419	8.5	22	210	0.81	7.6	12	.0029		4
1078S	04-2392	F	III	L	78012	401	10.2	20	220	0.74	8.0	20	.0024		6
1037A	01-2246	M	S	C	77230	400	10.3	160	1700	6.1	62.	8	.025		22
1041A	02-2246	M	S	A	77230	369	10.0	54	580	2.0	21.	4	.010		4
1037T	03-2268	F	S	B	77244	414	8.5	170	1500	6.4	54.	10	.022		26
1040D	04-2268	M	S	E	77244	396	10.3	23	250	0.85	9.3	2	.0051		1
1054D	02-2294	M	S	G	77272	391	7.9	200	1700	7.3	61.	10	.027		31
1049T	04-2294	F	S	D	77272	399	9.7	28	280	1.0	10.	2	.0056		1
1054C	02-2320	M	S	I	77292	411	7.0	180	1300	6.5	47.	9	.025		29
1049V	04-2320	F	S	F	77292	419	9.3	160	1500	5.9	57.	7	.028		17
1065T	03-2350	F	S	H	77313	390	7.9	81	640	3.0	24.	4	.016		6
1064C	04-2350	M	S	K	77313	391	8.5	46	410	1.7	15.	2	.0088		2
1067U	02-2390	F	S	J	78011	435	6.9	88	700	3.3	26.	9	.015		13.
1078T	03-2390	F	S	L	78011	400	10.2	41	470	1.5	17.	4	.0075		3.
1037E	01-2249	M	C	A	77231	401	10.0								
1040A	02-2249	M	C	C	77231	383	13.5								
1044T	01-2270	F	C	B	77244	380	7.1								
1043A	02-2270	M	C	E	77244	382	10.8								
1058A	01-2293	M	C	G	77271	369	10.0								
1051T	02-2293	F	C	D	77271	395	7.5								
1058S	01-2324	F	C	F	77305	403	10.5								
1062A	02-2324	M	C	I	77305	384	11.2								
1066T	01-2347	F	C	H	77312	376	7.0								
1062C	02-2347	M	C	K	77312	391	11.5								
1077T	01-2394	F	C	L	78045	440	8.8								
1068V	02-2394	F	C	J	78045	464	9.5								

****

EXPOSURE GROUPS:
GROUP I: SINGLE EXPOSURE TO 0.1UCI; THEN SHAM EXPOSURE EVERY 182 DAYS.
GROUP II: LUNG BURDEN INCREASED 0.1UCI EVERY 182 DAYS.
GROUP III: LUNG BURDEN INCREASED 0.01UCI EVERY 182 DAYS.
GROUP S: SACRIFICE SERIES; EXPOSURES AS FOR GROUP II.
GROUP C: CONTROLS; SHAM EXPOSURE EVERY 182 DAYS.

NOTES:
TLB (WBC)= TOTAL PLUTONIUM ACTIVITY INHALED BASED ON WHOLE BODY COUNTS OF 169YB TAG.
DOSE AND DOSE RATE ARE FOR LUNG AND INCLUDE ACTIVITY IN TRACHEOBRONCHIAL LYMPH NODES.
D, E, OR S INDICATE THE DOG DIED, WAS EUTHANIZED OR WAS SACRIFICED, RESPECTIVELY. PROMINATE FINDINGS ARE INCLUDED.

1

MAXIMUM ALPHA DOSE RATE GY/DAY	CUMULATIVE ALPHA RADIATION DOSE TO LUNG (GY) TO 9-30-91	TO DEATH	DEATH DATE	DAYS FROM FIRST EXPOSURE TO 9-30-91	DEATH	COMMENT
.0027		6.6	87104		3463	E-CARCINOMA, LUNG
.0029		8.9	89354		4444	D-BRONCHOPNEUMONIA
.0021		6.2	89163		4253	D-PAPILLARY ADENOCARCINOMA,LUNG
.0037		11.	87195		3533	E-CARCINOMA, LUNG
.0031		11.	89225		4294	D-PAPILLARY ADENOCARCINOMA,LUNG
.0026		8.2	88224		3927	E-PAPILLARY ADENOCARCINOMA, LUNG
.0031		11.	89213		4282	D-PAPILLARY ADENOCARCINOMA,LUNG
.0026		7.8	89220		4226	E-HEMANGIOSARCOMA,VERTEBRA
.0022		3.8	84271		2450	E-MELANOMA,OROPHARYNX
.0029		4.2	83118		1933	D-ACCIDENTAL DEATH
.0024		6.2	87349		3624	E-PAPILLARY ADENOCARCINOMA, LUNG
.025		22.	81299		1530	E-PNEUMONITIS AND PULMONARY FIBROSIS
.010		4.1	79228		728	S-SACRIFICED
.022		26.	82116		1698	D-PNEUMONITIS AND PULMONARY FIBROSIS
.0051		1.1	78243		364	S-SACRIFICED
.027		31.	82284		1838	S-SACRIFICED
.0056		1.5	78276		369	S-SACRIFICED
.025		29.	82298		1832	S-SACRIFICED
.028		17.	81098		1267	E-PNEUMONITIS AND PULMONARY FIBROSIS
.016		6.0	79311		728	S-SACRIFICED
.0088		2.5	78312		364	S-SACRIFICED
.015		13.	82299		1749	S-SACRIFICED
.0075		3.2	80015		734	S-SACRIFICED
			91198		5080	E-MELANOMA,MOUTH
			83290		2250	D-ACCIDENTAL DEATH
				5142		
			88168		3941	E-CARCINOMA, PERIANAL GLAND
				5115		
			89096		4208	D-CONGESTIVE HEART FAILURE
				5081		
			80179		969	D-STRANGULATED HERNIA
				5074		
			91249		5050	D-BRONCHOPNEUMONIA
			91029		4732	E-CARCINOMA,PITUITARY
			90045		4383	E-ADENOCARCINOMA, MAMMARY GLAND

:INDINGS ARE INCLUDED.

2

This appendix contains detailed tabular information through September 30, 1991, on all dogs in the life-span studies and many related sacrifice series associated with these studies that have been initiated at the University of Utah over the past 35 years. All of the dogs remaining alive in the life-span studies at the University of Utah were transferred to the Lovelace ITRI colony on September 15, 1987, where they are being maintained and studied for the remainder of their life spans. Responsibility for managing the completion of the Utah life-span studies has been assigned to ITRI, with input from a small team of investigators at the University of Utah and investigators at ITRI.

Appendix tables of this kind have been an important part of the annual reports from the Utah studies, and they will be continued as part of future ITRI annual reports. For consistency, the format of the Utah tables is similar to that used in past reports.

The following tables detailed information on the toxicity and test animals, respectively. Toxicity animals are those animals that were usually maintained until sacrifice became a clinical necessity; test animals were sacrificed as needed for special studies.

Dogs were put into the toxicity study at graded injection levels. At each level, about half the dogs were male and half female. Litter mates were used whenever possible. Abnormal dogs were excluded. Each animal received the designated quantity of one radionuclide in a single intravenous injection of 0.08 molar citrate solution at pH 3.5. Unless otherwise specified, the radionuclides were monomeric (either ionic or complexed with citrate).

The five injection levels designated by integers are those specified at the early meetings of the consultants; those designated by nonintegers have been added by the laboratory staff. Since those injection levels were originally specified in "retained" activities, the actual injections were four times the desired "retained" μCi/kg for ^{90}Sr, ^{210}Pb, ^{224}Ra, ^{226}Ra, and ^{228}Ra, and 1.11 times the desired "retained" μCi/kg for ^{228}Th, ^{239}Pu, ^{241}Am, $^{243,244}Cm$, ^{249,} ^{252}Cf, and ^{253}Es.

$$\text{Level 1} = 10 \times \frac{0.1\ \mu\text{Ci}\ ^{226}\text{Ra}}{70\ \text{kg man}} = 0.0143\ \text{retained}\ \mu\text{Ci/kg}$$

The desired "retained" activities were the same for all the radionuclides except ^{90}Sr, in which case they were greater by a factor of 10. Injection level 1 was the basis of the scheme, and was 10 times the maximum permissible concentration of ^{226}Ra in man.

Since radioactive decay and excretion occur continuously, the term "total body retention" is meaningless unless the time after injection is specified. Our present measurements indicate that the effective retention of alkaline earth elements and ^{210}Pb decrease to about 25% of that injected by the following times after injection.

Element	Time (days)
^{90}Sr	134
^{210}Pb	98
^{224}Ra	5
^{226}Ra	271
^{228}Ra	214

Retention of actinide elements decreased to about 90% at post-injection times shown below:

^{228}Th	6
^{239}Pu	6
^{241}Am	6
$^{243244}Cm$	1
^{253}Es	1

All other injection levels were simple multiples of level 1, as shown below.

Level 0.1 is 1/27 of level 1

Level 0.2 is 1/9 of level 1

Level 0.5 is 1/3 of level 1

Level 0.7 is 2/3 of level 1

Level 1.5 is 2 times level 1

Level 1.7 is 3 times level 1

Level 2 is 6 times level 1

Level 3 is 18 times level 1

Level 4 is 54 times level 1

Level 4.5 is 94 times level 1

Level 5 is 162 times level 1.

The numbering system for the dogs was built around the injection program and serves as a code to describe each dog's place in the experiment. The first letter tells the sex of toxicity animals (M = male; F = female). When the first letter is T, the dog is a test animal. M, F, or T is followed by a number which denotes chronological order of the individual test dogs, or of groups, in the case of toxicity dogs.

Next comes a code letter for the radionuclide: C = $^{243/244}Cm$; E = ^{253}Es; F = ^{252}Cf; G = ^{249}Cf; J = ^{85}Sr; K = $^{237,241}Pu$; L = ^{210}Pb; M = ^{228}Ra; P = ^{239}Pu; Q = ^{224}Ra; R = ^{226}Ra; S = ^{90}Sr; T = ^{228}Th; U = $^{233,232}U$; V = ^{238}U; W = ^{241}Am; A = ancillary (nonradioactive).

"A" following the regular dog number means that the dog is a replacement; "H" following the regular dog number means that the dog received more than one injection. "B", "C" or "D" denotes an intended special assignment, but most of these dogs have been redesignated for life-span toxicity studies. "E" in the final position is used to denote that the dog listed is a St. Bernard. "P" in the final position indicates that the nuclide was polymeric (injected in a particulate form). "Y" in the final position indicates that the animal was injected as a juvenile. "N" in the final position indicates that the animal was injected as a neonate. A plus (+) in the final position denotes that the animal was "old" when injected. Letters denoting a radionuclide may follow the final number, in which case the letter indicates that two radionuclides were given. The injection level refers to the radionuclide appearing first in the identifying code.

Example: M1R5 is a male animal in the first radium group at the highest injection level.

Although M1R5, M1R4, M1R3, M1R2, M1R1, and M1R0 constitute a group and were injected at the same time, the tables are arranged according to injection level to facilitate comparison of all the R5 animals, all the R4 animals, etc.

The conditions listed in the status tables under "Comments on Dead Dogs" give the cancers and the lesions that had the most apparent effect on the clinical status of the animal. These comments should not be considered as confirmed pathology. For example, multiple rib fractures, which seldom produce symptoms, are not listed, even though their incidence was usually much higher than the crippling fractures involving the limb bones or mandible. The hematological changes have been omitted unless they were extreme. Increased rate of tooth loss, hepatic changes, eye lesions, and many other factors in the various syndromes have not been included because of space limitations. Over the years many soft tissue tumors have been removed surgically. In many instances, the conditions that have been listed were the reasons for sacrifice of the animal but they were not the immediate cause of death. Most of the animals were euthanized when death appeared imminent or when life could no longer be prolonged humanely.

DOSIMETRY

The tables include the calculated average dose in Gy to the skeleton at death. ^{90}Sr, ^{226}Ra, ^{228}Ra, ^{241}Am, ^{249}Cf, and ^{252}Cf doses are calculated for each dog, using its individually observed retention values; ^{239}Pu, ^{228}Th, and ^{224}Ra doses are based on the average retention equations. For the young adult Beagle dogs injected at about 17 mo of age, the following equations were used for the EFFECTIVE skeletal retention at (t) days after injection to account for both radioactive decay and biological elimination. These equations do not apply to St. Bernards (E) or to Beagles injected as neonates (N), young juveniles (Y), old dogs (+), or to dogs receiving polymeric plutonium (P) or chelation therapy.

Detailed retention data and dosimetric analyses were presented or referenced in the 1984 annual report (C00-119-259, December 1984). The skeletal doses are based upon a wet skeleton which is 10% of the body weight at the time of injection (C00-119-257, pp. 89-92, 1982).

^{228}Ra and ^{226}Ra doses deserve special comment. The dose from "pure" ^{228}Ra and its *in vivo* produced daughters is based on our best evaluation of 5.77 ± 0.02 yr for the ^{228}Ra half-period. The tabulated total doses include the contributions from ^{228}Th contamination in the injection solutions. For example, ^{228}Th contaminations of 0.6%, 3% and 15%, respectively, account for 3%, 13% and 42% of the total dose in rads at 1000 days. If injected ^{228}Th is four times more toxic rad-for-rad than is *in vivo* produced ^{228}Th, these injected ^{228}Th contamination would account for 10%, 37% and 74% of the total biological damage at 1000 days. Therefore, it may be desirable to use only results from the slightly contaminated (0.6% ^{228}Th) dogs in evaluation of ^{228}Ra toxicity. The contribution from injected ^{210}Pb which occurs in the ^{226}Ra injection solution as a result of ^{226}Ra decay has been included in skeleton dose calculations for ^{226}Ra dogs. This can account for between about 1% and 30% of the total:

^{226}Ra (adults, dose level 5) $= 0.20e^{-0.00488t} + 0.29e^{-0.000299t}$

^{226}Ra (adults, lower levels) $= 0.21e^{-0.0155T} + 0.18e^{-0.00204t} + 0.15e^{-0.000150t}$

$^{222}Rn/^{226}Ra$ (adults, all levels) $= 0.075\ (1-e^{-0.181t})\ t^{0.158}$

^{239}Pu (dose level 5) $= 0.07e^{-0.0011t} + 0.43$

^{239}Pu (dose level 4) $= 0.11e^{-0.0011t} + 0.39$

^{239}Pu (dose level 3) $= 0.15e^{-0.0011t} + 0.34$

^{239}Pu (lower levels) $= 0.29e^{-0.0011t} + 0.21$

^{228}Ra (all levels) = $0.21e^{-0.016t} + 0.177e^{-0.0024t} + 0.15e^{-0.00048t}$ (pure at $t = 0$) with 84% retention of *in vivo* produced daughters of ^{228}Th.

^{228}Th (all levels) = $0.68e^{-0.00117t}$ with ratios of ^{224}Ra, ^{220}Rn, ^{216}Po, ^{212}Pb, ^{212}Bi to ^{228}Th as a function of time after injection and of dose level as given in *Radiat. Res. 98*: 614-628, 1984.

^{241}Am (dose level 5) = $0.359 + 0.157\ (1\text{-}e^{-0.0065t})$

^{241}Am (dose level 4) = $0.359 + 0.141\ (1\text{-}e^{-0.0029t})$

^{241}Am (dose level 3) = $0.359 + 0.076\ (1\text{-}e^{-0.0021t})$

^{241}Am (lower levels) = $0.359 + 0.015\ (1\text{-}e^{-0.0014t})$

^{249}Cf (all levels) = $0.498e^{-0.0000794t}$

^{252}Cf (all levels) = $0.498e^{-0.000791t}$

^{224}Ra (all levels) = $0.528e^{-0.214t} - 0.228e^{-9.01t}$ with the effective retention of ^{224}Ra daughters for all levels of:

^{220}Rn and ^{216}Po = $0.486e^{-0.214t} - 0.276e^{-4.65t}$

^{212}Pb = $0.447e^{-0.214t} - 0.336e^{-2.40t}$

^{212}Bi = ^{212}Po + ^{208}Tl = $0.391e^{-0.214t} - 0.350e^{-2.38t}$

For the calculation of radiation dose for dogs that had received particulate plutonium, measured skeletal weights were used. The following skeletal Pu-retentions (R_{Skel}) were applied:

1. Dogs that received no further treatment: $R_{Skel} = 60(1 - 0.914e^{0.00098t})e^{-0.000237t}$.
2. Dogs that received 30 μmole CaDTPA/kg once weekly: R_{Skel} = 6.7% constant average retention.
3. Dogs that received 30 μmole ZnDTPA/kg daily: R_{Skel} = 2.8% constant average retention.

STATUS TABLES

B.I ^{241}Am, Chronic Toxicity Study

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F013W02	533	10.6	0.00179	0.0662	OCT-13-66	3815	0.06	UNDETERMINED (NO SKELETAL TUMOR)
M014W02	533	14.9	0.00178	0.0659	OCT-13-66	3185	0.05	HEMANGIOSARCOMA (SOFT TISSUE)
F024W02	477	11.3	0.00181	0.0670	MAR-21-68	4236	0.08	THROMBOEMBOLISM
F031W02	472	10.9	0.00180	0.0666	MAY-08-68	1478	0.03	LUNG CARCINOMA
M041W02	467	11.9	0.00180	0.0666	JUL-02-68	4860	0.09	THYMOMA
M048W02	484	11.0	0.00174	0.0644	JUL-30-68	4705	0.07	MAST CELL SARCOMA
M049W02	498	10.7	0.00175	0.0648	NOV-25-69	4026	0.07	VALVULAR ENDOCARDITIS, PNEUMONIA
F058W02	496	10.4	0.00168	0.0622	JAN-26-70	3157	0.05	TRAUMA
M062W02	485	13.3	0.00175	0.0648	FEB-24-70	4996	0.09	SPONDYLOSIS, LUNG CARCINOMA
F069W02	542	10.8	0.00180	0.0666	APR-22-70	4287	0.07	ENDOMETRITIS
M078W02	501	13.5	0.00178	0.0659	JUL-16-70	4884	0.10	PNEUMONIA
M079W02	501	10.0	0.00179	0.0662	JUL-16-70	4694	0.08	EPIDERMOID CARCINOMA (MOUTH)
F088W02	531	8.36	0.00177	0.0655	AUG-25-70	3335	0.05	PANCREATITIS
M095W02	526	13.1	0.00173	0.0640	AUG-25-70	4129	0.08	LYMPHOSARCOMA, LUNG ADENOCARCINOMA
F011W05	533	8.17	0.00532	0.197	OCT-13-66	4758	0.24	FIBROSARCOMA (LIVER)
M012W05	533	11.9	0.00539	0.199	OCT-13-66	3649	0.19	UNDETERMINED (NO SKELETAL TUMOR)
M023W05	486	12.2	0.00530	0.196	MAR-21-68	5054	0.31	HEMANGIOSARCOMA (SOFT TISSUE)
M029W05	472	10.4	0.00548	0.203	MAY-08-68	2239	0.14	MELANOMA (MOUTH)
F030W05	472	10.6	0.00538	0.199	MAY-08-68	4768	0.27	PANCREATITIS
F040W05	467	9.40	0.00528	0.195	JUL-02-68	4171	0.20	MAMMARY ADENOCARCINOMA, HEMORRHAGE (LIVER)
M050W05	552	11.8	0.00526	0.195	NOV-25-69	4962	0.26	MALIGNANT MELANOMA
M059W05	496	11.5	0.00503	0.186	JAN-26-70	4566	0.23	HEPATIC CELL CARCINOMA
M063W05	485	11.4	0.00524	0.194	FEB-24-70	5421	0.30	HEMANGIOSARCOMA (SOFT TISSUE)
M070W05	497	12.8	0.00531	0.195	APR-22-70	4510	0.27	NEPHRITIS
F080W05	501	11.9	0.00545	0.202	JUL-16-70	4555	0.23	CHONDROSARCOMA, FIBROSARCOMA (SKELETON)
F081W05	501	12.1	0.00548	0.203	JUL-16-70	5306	0.30	UNDETERMINED (NO TUMOR)
F089W05	531	9.66	0.00527	0.195	AUG-25-70	4433	0.26	MAMMARY ADENOCARCINOMA
M096W05	490	12.0	0.00533	0.197	AUG-25-70	3283	0.17	INTUSSUSCEPTION
F009W10	517	8.60	0.0160	0.592	SEP-15-66	5265	0.79	CHOLANGIOCARCINOMA, SENILITY
F010W10	517	9.90	0.0162	0.599	SEP-15-66	2750	0.44	LUNG CARCINOMA
M020W10	513	10.8	0.0161	0.596	MAR-21-68	3060	0.51	LIVER MYXOSARCOMA
F021W10	513	9.36	0.0166	0.614	MAR-21-68	232	0.04	ACCIDENTAL STRANGULATION
F021W10A	552	11.4	0.0159	0.588	NOV-25-69	3262	0.57	MAST CELL SARCOMA
M022W10	486	11.6	0.0164	0.607	MAR-21-68	4793	0.88	CHONDROSARCOMA (L. RIB #10)
M028W10	472	12.1	0.0158	0.585	MAY-08-68	3632	0.56	EPIDERMOID CARCINOMA (MOUTH)
F051W10	552	8.25	0.0163	0.603	NOV-25-69	4328	0.72	DEGENERATION (KIDNEY), PNEUMONIA
M060W10	496	10.0	0.0157	0.581	JAN-26-70	4785	0.70	OSTEOSARCOMA, LUNG ADENOCARCINOMA, NEPHRITIS
M064W10	485	10.4	0.0158	0.585	FEB-24-70	3134	0.56	THROMBOEMBOLISM
F071W10	485	12.1	0.0157	0.581	APR-22-70	3891	0.58	FIBROSARCOMA (SKELETON)
M082W10	501	12.4	0.0163	0.603	JUL-16-70	4855	0.82	CHOLANGIOCARCINOMA
F090W10	526	10.9	0.0160	0.592	AUG-25-70	3998	0.63	LUNG CARCINOMA
M097W10	490	10.4	0.0160	0.592	AUG-25-70	2530	0.46	THROMBOEMBOLISM
F122W10	504	9.38	0.0150	0.555	NOV-06-75	4491	0.51	PYOMETRA (UTERUS)

B.1 ^{241}Am, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M123W10	516	11.8	0.0156	0.577	DEC-09-75	4607	0.62	INTERSTITIAL PNEUMONIA (LUNG)
F124W10	516	8.36	0.0157	0.581	DEC-09-75	4728	0.65	SQUAMOUS CELL CARCINOMA, ORAL MUCOSA
F127W10	494	8.89	0.0152	0.562	NOV-06-75	4683	0.57	CHOLANGIOCARCINOMA (LIVER)
M128W10	493	13.2	0.0153	0.566	NOV-06-75	4901	0.75	ANESTHETIC DEATH/RENAL DISEASE
F130W10	491	10.3	0.0153	0.566	NOV-06-75	3783	0.45	PNEUMONIA,FIBROSARC.(LIVER),MYELOPROLIFERATIVE DISEASE
M132W10	482	9.86	0.0153	0.566	NOV-06-75	4396	0.56	HEMANGIOSARCOMA, CHOLANGIOCARCINOMA (LIVER)
M134W10	489	9.03	0.0150	0.555	NOV-06-75	5093	0.79	GLOMERULONEPHRITIS;TRANSITIONAL CELL CARC., PROSTATE
F137W10	515	7.71	0.0154	0.570	DEC-09-75	5314	0.77	HEMANGIOSARCOMA, LIVER
F138W10	514	8.63	0.0152	0.562	DEC-09-75	3270	0.45	TRANSITIONAL CELL CARCINOMA (URNARY BLADDER)
M139W10	513	9.11	0.0157	0.581	DEC-09-75	4063	0.66	CARCINOMA (DUODENUM)
F141W10	504	8.89	0.0154	0.570	DEC-09-75	3612	0.55	MELANOMA (ORAL)
F042W17	495	9.26	0.0484	1.79	JUL-30-68	2960	1.59	MAST CELL SARCOMA (LIVER)
F043W17	492	10.4	0.0481	1.78	JUL-30-68	3666	1.82	SURGICAL COMPLICATIONS
F044W17	492	7.46	0.0473	1.75	JUL-30-68	3306	1.84	MAST CELL SARCOMA
M045W17	492	11.9	0.0486	1.80	JUL-30-68	4012	2.02	OBSTRUCTION (VENA CAVA)
M046W17	484	8.42	0.0479	1.77	JUL-30-68	2848	1.25	STATUS EPILEPTICUS
M047W17	484	11.1	0.0486	1.80	JUL-30-68	3486	1.72	HEMORRHAGE (LIVER)
F052W17	552	9.57	0.0493	1.82	NOV-25-69	4307	2.15	OSTEOSARCOMA, LUNG CARCINOMA
M061W17	496	10.7	0.0458	1.69	JAN-26-70	3767	1.70	OSTEOSARCOMA
M065W17	485	11.2	0.0471	1.74	FEB-24-70	3680	1.79	MAST CELL SARCOMA (LIVER)
F072W17	500	11.1	0.0479	1.77	APR-22-70	4293	2.13	OSTEOSARCOMA, FIBROSARCOMA (SOFT TISSUE)
M083W17	501	12.6	0.0493	1.82	JUL-16-70	3925	2.03	CHOLANGIOCARCINOMA
F091W17	490	13.3	0.0480	1.78	AUG-25-70	2193	0.94	BLOOD DYSCRASIA
M098W17	490	13.3	0.0480	1.78	AUG-25-70	3790	2.08	OSTEOSARCOMA
F115W17	502	8.73	0.0468	1.73	OCT-17-74	3942	2.17	COLLAPSED VERTEBRA, OSTEOPOROSIS
F116W17	502	8.56	0.0470	1.74	OCT-17-74	3464	2.17	OSTEOSARCOMA
F121W17	504	9.36	0.0458	1.69	NOV-06-75	2982	1.15	UNDETERMINED (NO TUMOR)
M125W17	515	10.0	0.0471	1.74	DEC-09-75	3601	1.61	OSTEOSARCOMA,CHOLANGIOCARC., HEMANGIOSARC. (LIVER)
F126W17	494	9.63	0.0456	1.69	NOV-06-75	3903	1.53	EPIDERMOID CARCINOMA, OSTEOSARCOMA
M129W17	493	8.26	0.0453	1.68	NOV-06-75	2624	1.38	OSTEOSARCOMA
F131W17	491	9.16	0.0457	1.69	NOV-06-75	4200	1.62	AORTIC BODY TUMOR
M133W17	491	10.8	0.0459	1.70	NOV-06-75	3452	1.50	UNDIFFERENTIATED SARCOMA (ILEUM, SMALL INTESTINE)
M135W17	489	10.0	0.0458	1.69	NOV-06-75	3227	1.86	OSTEOSARCOMA
F136W17	522	8.91	0.0461	1.71	DEC-09-75	1343	0.63	TRAUMA, THROMBOEMBOLISM
M140W17	513	10.5	0.0469	1.74	DEC-09-75	2691	1.33	FIBROSARCOMA (LIVER)
F007W20	560	12.6	0.0952	3.52	SEP-15-66	1847	1.67	OSTEOSARCOMA
F008W20	560	11.7	0.0957	3.54	SEP-15-66	2841	2.68	OSTEOSARCOMA
M019W20	513	13.4	0.0970	3.59	MAR-21-68	2785	2.71	FIBROSARCOMA (LIVER)
M027W20	472	12.7	0.0961	3.56	MAY-08-68	2887	2.56	MAST CELL SARCOMA
M038W20	477	9.88	0.0945	3.50	JUL-02-68	3047	3.15	OSTEOSARCOMA
F039W20	468	9.21	0.0948	3.51	JUL-02-68	3066	3.45	OSTEOSARCOMA, NOSE ADENOCARCINOMA
M053W20	498	9.24	0.0960	3.55	NOV-25-69	3055	3.21	OSTEOSARCOMA
F066W20	485	9.12	0.0935	3.46	FEB-24-70	3341	3.93	OSTEOSARCOMA
M073W20	553	14.3	0.0965	3.57	JUN-17-70	2476	2.39	COLLAPSED VERTEBRA

B.1 ^{241}Am, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F084W20	493	10.6	0.0984	3.64	JUL-16-70	2773	2.93	OSTEOSARCOMA
M085W20	493	10.8	0.0987	3.65	JUL-16-70	3424	3.67	OSTEOSARCOMA, FIBROSARCOMA (LIVER)
F092W20	490	10.6	0.0962	3.56	AUG-25-70	2318	2.54	OSTEOSARCOMA
M005W30	560	15.0	0.305	11.3	SEP-15-66	1917	5.84	OSTEOSARCOMA
F006W30	560	11.9	0.310	11.5	SEP-15-66	1510	4.70	OSTEOSARCOMA
F018W30	522	8.60	0.307	11.4	MAR-21-68	1756	6.07	OSTEOSARCOMA
M026W30	472	12.4	0.310	11.5	MAY-08-68	2127	7.54	OSTEOSARCOMA, FIBROSARC.(SKELETON), HEPATIC CELL CARC.
M036W30	477	11.0	0.305	11.3	JUL-02-68	1696	5.53	OSTEOSARCOMA
F037W30	468	8.44	0.294	10.9	JUL-02-68	1764	5.29	OSTEOSARCOMA
M054W30	498	10.5	0.306	11.3	NOV-25-69	1876	7.15	OSTEOSARCOMA
M067W30	485	11.8	0.295	10.9	FEB-24-70	1883	6.67	DEGENERATION (LIVER AND KIDNEY)
F074W30	542	10.0	0.302	11.2	APR-22-70	1700	5.36	OSTEOSARCOMA
F075W30	556	9.42	0.308	11.4	JUN-17-70	1533	5.65	OSTEOSARCOMA
M086W30	493	11.3	0.312	11.5	JUL-16-70	1558	5.62	OSTEOSARCOMA
F093W30	490	11.2	0.301	11.1	AUG-25-70	1884	6.66	OSTEOSARCOMA
M100W30	542	11.0	0.304	11.2	DEC-02-70	1198	4.24	OSTEOSARCOMA
M003W40	516	12.6	0.897	33.2	JUN-28-66	1779	20.6	OSTEOSARCOMA, NEPHRITIS
F004W40	516	9.40	0.911	33.7	JUN-28-66	1533	17.7	DEGENERATION (KIDNEY AND THYROID)
M017W40	522	9.87	0.924	34.2	MAR-21-68	1132	12.6	OSTEOSARCOMA, THROMBOEMBOLISM
F025W40	472	10.5	0.927	34.3	MAY-08-68	1527	18.2	LIVER MESOTHELIOMA, DEGENERATION (KIDNEY)
M034W40	477	10.7	0.893	33.0	JUL-02-68	1566	14.8	OSTEOSARCOMA
F035W40	477	8.87	0.902	33.4	JUL-02-68	1323	15.2	HEPATIC MESOTHELIOMA
F055W40	498	8.37	0.914	33.8	NOV-25-69	1388	17.6	OSTEOSARCOMA
M068W40	485	11.8	0.890	32.9	FEB-24-70	1415	14.6	OSTEOSARCOMA
F076W40	485	9.37	0.899	33.3	APR-22-70	1569	18.0	OSTEOSARCOMA
M077W40	500	10.5	0.906	33.5	APR-22-70	633	6.98	DEGENERATION (LIVER)
M087W40	501	13.1	0.916	33.9	JUL-16-70	1300	13.9	OSTEOSARCOMA
F094W40	490	11.3	0.912	33.7	AUG-25-70	1381	15.9	OSTEOSARCOMA
M001W50	517	10.4	2.78	103.	JUN-28-66	401	14.5	DEGENERATION (LIVER AND KIDNEY)
M002W50	517	12.7	2.83	105.	JUN-28-66	448	16.0	DEGENERATION (LIVER AND KIDNEY)

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MEASUREMENTS MADE TO DATE INDICATE THE LIVER DOSE FROM AM-241 TO BE APPROXIMATELY TWO TIMES THAT TO THE SKELETON.

THE ORIGINAL "T" (TEST) DESIGNATION FOR THE ABOVE ANIMALS HAS BEEN CHANGED TO "M" AND "F" (MALE OR FEMALE) TOXICITY DESIGNATIONS. FOR EXAMPLE, THE MALE DOG ORIGINALLY INJECTED AS T001W50 IS NOW DESIGNATED M001W50.

B.2 ^{249}Cf, Chronic Toxicity Study

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F001G00	499	7.77			OCT-23-73	4481		NEPHRITIS
M002G00	509	10.5			NOV-28-72	3122		MYELOID SARCOMA
M003G00	509	10.1			NOV-28-72	4969		PNEUMONIA
F004G00	502	11.1			MAR-05-74	269		ACCIDENTAL STRANGULATION
F005G00	514	11.0			MAY-30-74	5297		HEART BLOCK/LIVER ATROPHY
M006G00	499	11.4			OCT-23-73	5873		DISC PROTRUSION; MELANOMA, ORAL
F001G01	499	9.91	.00061	0.0226	OCT-23-73	4636	0.04	MAMMARY ADENOCARCINOMA
M002G01	486	13.1	.00063	0.0233	JUL-05-72	2678	0.02	INFECTION (BACTERIAL)
M003G01	486	10.1	.00063	0.0233	JUL-05-72	3633	0.03	ANKYLOSING SPONDYLITIS
F004G01	488	11.4	.00060	0.0222	APR-24-74	5241	0.04	AXONAL DEGENERATION (BRAINSTEM)
F005G01	488	8.70	.00060	0.0222	APR-24-74	5445	0.04	MALIGNANT MELANOMA, ORAL MUCOSA
M006G01	486	11.6	.00064	0.0237	JUL-05-72	4998	0.04	MESOTHELIOMA (PLEURA)
F001G05	499	9.20	.00485	0.179	OCT-23-73	5916	0.42	PYELONEPHRITIS
M002G05	514	12.0	.00514	0.190	FEB-29-72	5105	0.38	EPIDERMOID CARCINOMA (ORAL)
M003G05	514	12.6	.00518	0.192	FEB-29-72	3668	0.26	EPIDERMOID CARCINOMA (ORAL)
F004G05	471	10.9	.00516	0.191	MAR-05-74	4208	0.36	MAMMARY ADENOCARCINOMA
F005G05	504	11.3	.00559	0.207	MAY-30-74	3788	0.33	ADENOCARCINOMA (LUNG)
M006G05	514	11.8	.00511	0.189	FEB-29-72	2037	0.16	NOSE ADENOCARCINOMA
F001G10	555	8.58	.0154	0.570	DEC-16-71	1584	0.35	STATUS EPILEPTICUS
M002G10	486	11.4	.0152	0.562	JUL-05-72	4352	0.91	CHOLANGIOCARCINOMA
M003G10	486	11.5	.0154	0.570	JUL-05-72	3849	0.82	BILIARY OBSTRUCTION
F004G10	555	10.5	.0154	0.570	DEC-16-71	4744	0.93	PNEUMONIA
F005G10	471	9.29	.0153	0.566	MAR-05-74	3063	0.54	HYDRONEPHROSIS
M006G10	524	10.6	.0160	0.592	NOV-28-72	4586	0.98	MELANOMA (MOUTH)
F001G20	558	9.32	.0905	3.35	DEC-16-71	2029	2.75	OSTEOSARCOMA
M002G20	555	11.0	.0916	3.39	DEC-16-71	2301	3.08	EPIDERMOID CARCINOMA (TYMPANIC BULLA)
M003G20	486	10.8	.0935	3.46	JUL-05-72	2618	3.28	OSTEOSARCOMA
F004G20	558	10.3	.0915	3.39	DEC-16-71	2561	3.23	OSTEOSARCOMA
F005G20	555	9.44	.0913	3.38	DEC-16-71	2821	3.63	OSTEOSARCOMA
M006G20	524	10.0	.0963	3.56	NOV-28-72	3037	4.45	OSTEOSARCOMA
F001G30	584	11.6	.290	10.7	FEB-24-71	1716	7.10	OSTEOSARCOMA
M002G30	580	13.2	.282	10.4	FEB-24-71	1770	7.22	OSTEOSARCOMA
M003G30	580	13.7	.284	10.5	FEB-24-71	1464	5.84	OSTEOSARCOMA
F004G30	580	8.79	.283	10.5	FEB-24-71	1541	6.89	OSTEOSARCOMA
F005G30	514	9.12	.300	11.1	MAY-30-74	1657	7.43	OSTEOSARCOMA
M006G30	524	10.1	.293	10.8	NOV-28-72	1322	5.97	OSTEOSARCOMA

B.3 ^{252}Cf, Chronic Toxicity Study

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M001F00	562	12.0			FEB-01-72	3240		FIBROSARCOMA (SOFT TISSUE)
F002F00	545	10.6			JAN-03-73	3968		MAMMARY ADENOCARCINOMA
F003F00	545	9.43			JAN-03-73	2806		EPIDERMOID CARCINOMA (NOSE)
F004F00	492	10.6			FEB-27-73	5537		PYELONEPHRITIS (KIDNEY)
M005F00	562	10.4			FEB-01-72	3720		PNEUMONIA
M006F00	509	10.9			NOV-28-72	3871		FIBROSARCOMA (SOFT TISSUE)
M001F01	498	13.0	.00060	0.0222	JUL-26-72	4054	0.02	ADENOCARCINOMA
F002F01	524	9.15	.00064	0.0237	NOV-02-72	3949	0.02	UNDETERMINED (NO TUMOR)
F003F01	545	10.1	.00075	0.0278	JAN-03-73	4542	0.03	BRONCHIOLO-ALVEOLAR CARCINOMA
F004F01	492	9.44	.00060	0.0222	FEB-27-73	5949	0.02	NONPRODUCTIVE OSTEOBLASTIC OSTEOSARCOMA, VERTEBRA
M005F01	498	10.4	.00060	0.0222	JUL-26-72	3581	0.02	PNEUMONIA, EMPYEMA
M006F01	524	10.3	.00062	0.0229	NOV-02-72	5115	0.03	NEPHRITIS, SENILITY
M001F05	498	12.2	.00525	0.194	JUL-26-72	5308	0.20	LYMPHOSARCOMA
F002F05	513	11.0	.00529	0.196	NOV-02-72	4318	0.20	THROMBOEMBOLISM, PNEUMONIA
F003F05	511	8.89	.00525	0.194	FEB-27-73	4567	0.19	MELANOMA (MOUTH), MAMMARY ADENOCARCINOMA
F004F05	485	11.2	.00518	0.192	FEB-27-73	4348	0.19	HEMANGIOSARCOMA (SOFT TISSUE), ADENOCARCINOMA (OVARY)
M005F05	494	9.44	.00530	0.196	JUL-26-72	4348	0.20	KIDNEY FAILURE
M006F05	524	11.0	.00529	0.196	NOV-02-72	5096	0.20	NEPHRITIS
M001F10	586	9.69	.0163	0.603	SEP-08-71	3983	0.60	FIBROSARCOMA (SOFT TISSUE)
F002F10	586	8.28	.0167	0.618	SEP-08-71	5102	0.64	MAMMARY ADENOCARCINOMA, CHOLANGIOCARCINOMA
F003F10	539	8.89	.0167	0.618	SEP-08-71	4737	0.61	KIDNEY FAILURE
F004F10	539	10.0	.0165	0.611	SEP-08-71	3652	0.60	PLASMA CELL SARCOMA, THROMBOEMBOLISM
M005F10	539	12.9	.0165	0.611	SEP-08-71	5950	0.71	LIVER ATROPHY, CHOLANGIOCARCINOMA (LIVER)
M006F10	513	9.67	.0165	0.611	NOV-02-72	4120	0.63	UNDETERMINED (NO TUMOR)
M001F20	498	11.5	.0922	3.41	JUL-26-72	2813	3.30	OSTEOSARCOMA
F002F20	545	9.85	.0905	3.35	JAN-03-73	3695	3.47	OSTEOSARCOMA
F003F20	511	9.16	.0907	3.36	FEB-27-73	3584	3.02	OSTEOSARCOMA
F004F20	473	9.33	.0910	3.37	FEB-27-73	4103	3.25	HEMANGIOSARCOMA (SOFT TISSUE)
M005F20	494	10.2	.0905	3.35	JUL-26-72	4055	3.35	MELANOMA (MOUTH)
M006F20	513	11.4	.0912	3.37	NOV-02-72	3927	3.38	FIBROSARCOMA (SKELETON)
M001F30	583	11.6	.289	10.7	MAR-03-71	1546	8.10	FIBROSARCOMA (SKELETON)
F002F30	583	10.6	.289	10.7	MAR-03-71	1723	8.14	OSTEOSARCOMA
F003F30	583	8.66	.292	10.8	MAR-03-71	2030	8.38	OSTEOSARCOMA
F004F30	583	9.69	.295	10.9	MAR-03-71	2015	8.86	OSTEOSARCOMA
M005F30	524	11.1	.284	10.5	NOV-28-72	1675	8.47	OSTEOSARCOMA
M006F30	513	10.2	.293	10.8	NOV-02-72	1846	8.57	OSTEOSARCOMA

B.4 ^{253}Es, Chronic Toxicity Study

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F001E30	470	11.2	0.284	10.5	JUN-05-73	2586	0.15	DEGENERATION (KIDNEY), PNEUMONIA
M003E30	470	11.3	0.288	10.7	JUN-05-73	5167	0.15	UNDETERMINED
M004E30	470	7.93	0.294	10.9	JUN-05-73	4694	0.16	PNEUMONIA, HYPOTHYROIDISM
F001E50	495	8.70	2.85	5.45	JUN-05-73	2876	1.46	MAST CELL SARCOMA
F002E50G	483	9.21	2.81	104.	JUN-05-73	2009	7.53	OSTEOSARCOMA
M003E50	470	10.4	2.84	105.	JUN-05-73	4762	1.50	LUNG CARCINOMA

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F002E50G SUBSEQUENTLY RECEIVED 11.8 KBQ/KG (0.318 UCI/KG) OF CF-249 ON MAY 28, 1974, 7.34 OF THE TOTAL 7.53 GY WERE FROM CF-249.

B.5 ^{239}Pu, Chronic Toxicity Study

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M001P00	442	9.70			DEC-01-52	4003		RUPTURE (SPLEEN), SEMINOMA
F002P00	424	6.36			MAR-02-53	2755		ANESTHETIC ACCIDENT
M003P00	515	10.8			JUN-01-53	5362		PANCREAS ADENOCARCINOMA
M004P00	426	10.7			SEP-16-53	5138		THYROID ADENOCARCINOMA, NEPHRITIS
F005P00	620	9.75			OCT-14-53	4088		ADRENAL CORTEX ADENOCARCINOMA
F006P00	409	5.59			MAY-12-54	4490		THROMBOEMBOLISM
F007P00	515	6.90			OCT-25-54	5344		RHABDOMYOSARCOMA, MAMMARY ADENOCARCINOMA
M008P00	584	10.9			MAR-15-55	4072		CIRCULATORY FAILURE
F009P00	573	11.0			SEP-09-55	3032		THROMBOEMBOLISM, NEPHRITIS
F010P00	658	11.0			NOV-22-55	3971		LYMPHOSARCOMA
M011P00	602	10.3			APR-24-56	3821		FIBROSARCOMA (SOFT TISSUE)
M012P00	630	10.9			MAY-29-56	4143		CARCINOMA (TESTES)
F013P00	516	9.47			MAR-04-64	5361		OSTEOSARCOMA
F014P00	452	9.89			MAY-12-64	4105		ENDOMETRITIS
M015P00	526	12.1			OCT-23-64	3750		TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
M016P00	486	13.9			APR-07-65	4756		SENILITY
M017P00	551	12.2			NOV-08-66	5535		SENILITY THROMBOEMBOLISM
F018P00	535	11.4			NOV-29-66	4849		NEPHRITIS
M019P00	536	13.1			NOV-29-66	5203		FIBROSARCOMA (TURBINATES)
020P00	546	8.50			DEC-29-66	3748		PLEURAL EFFUSION
M021P00	549	13.3			JAN-26-67	4157		AORTIC BODY TUMOR
F022P00	489	10.6			MAY-25-67	4403		NEPHRITIS
M031P00B	452	11.8			MAY-12-64	1763		STATUS EPILEPTICUS, BILIARY OBSTRUCTION
M031P00C	452	12.6			MAY-12-64	3629		MELANOMA (MOUTH)
M032P00B	452	11.2			MAY-12-64	4840		CARDIAC INSUFFICIENCY
M032P00C	542	10.3			SEP-21-65	5046		SENILITY
M033P00B	516	12.1			SEP-21-65	4923		SENILITY
M033P00C	503	11.7			NOV-18-65	4164		INANITION, UNDETERMINED (NO SKELETAL TUMOR)
M034P00B	524	13.5			JAN-26-67	5487		MELANOMA (MOUTH), NEPHRITIS
M034P00C	484	12.7			MAR-22-67	4139		INANITION, UNDETERMINED (NO SKELETAL TUMOR)
M035P00B	484	12.5			MAR-22-67	5654		ASTROCYTOMA
M035P00C	484	13.1			MAR-22-67	3501		PARALYSIS (NO SKELETAL TUMOR)
M036P00B	489	11.0			MAY-25-67	2525		STATUS EPILEPTICUS
M036P00C	485	12.2			MAY-25-67	5244		DEGENERATION (KIDNEY), FASCIITIS
M037P00B	507	11.7			JUN-22-67	4179		INANITION, UNDETERMINED (NO SKELETAL TUMOR)
M037P00C	493	10.4			JUN-22-67	4485		PANCREATITIS
M038P00B	529	10.7			NOV-16-67	3623		TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
M038P00C	529	12.2			NOV-16-67	3382		PNEUMONIA
M039P00B	502	10.7			DEC-21-67	6061		CARCINOMA (AORTIC BODY, PROSTATE), SENILITY
M039P00C	502	10.1			DEC-21-67	5113		PNEUMONIA
M040P00B	484	10.3			JUL-30-68	4957		PANCREAS ADENOCARCINOMA, SEMINOMA
M040P00C	552	11.4			JAN-09-69	3377		PERIARTERITIS
M041P00B	560	9.49			JAN-17-69	3875		PANCREATITIS
M042P00	479	14.0			APR-24-74	3242		LYMPHOSARCOMA

B.5 ^{239}Pu, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M043P00	479	13.8			APR-24-74	4216		INTESTINAL CARCINOMA,BILIARY OBSTRUCTION
M044P00	479	12.7			APR-24-74	4648		PNEUMONIA
M045P00	497	11.5			AUG-29-74	1537		STATUS EPILEPTICUS
M046P00	497	11.5			AUG-29-74	5584		TRANSITIONAL CELL CARCINOMA, BLADDER
M047P00	497	11.3			AUG-29-74	3715		LYMPHOSARCOMA
M048P00	497	11.7			AUG-29-74	5983		HYDROCEPHALUS
M081P00Y	97	7.10			MAR-01-72	5718		HYPOTHERMIA,BRONCHIOALVEOLAR CARCINOMA (LUNG)
F082P00Y	97	7.30			MAR-01-72	4547		ENDOMETRITIS,PANCREATITIS
F083P00Y	91	3.97			APR-25-72	4696		PERFORATION (INTESTINE)
F084P00Y	89	3.67			APR-25-72	5202		MELANOMA (ORAL)
M086P00Y	91	4.37			APR-25-72	5381		UNDETERMINED (NO SKELETAL TUMOR)
F101P00Y								REASSIGNED,SEE F511R40+
M102P00Y								REASSIGNED,SEE M512R40+
F103P00Y								REASSIGNED,SEE T240P30+
M104P00Y								REASSIGNED,SEE T241P30+
M105P00Y	92	4.90			APR-27-76	1353		ACCIDENTAL STRANGULATION
F106P00Y								REASSIGNED,SEE T247P30+
M107P00Y	90	4.07			APR-27-76	2660		THROMBOEMBOLISM
F108P00Y								REASSIGNED,SEE T251P30+
M109P00Y	91	4.08			DEC-16-76	2736		STATUS EPILEPTICUS
F013P01	515	9.46	0.00068	0.0252	MAR-04-64	4492	0.02	TRANSITIONAL CELL CARC.(URINARY BLADDER),PERITONITIS
F014P01	452	10.3	0.00055	0.0204	MAY-12-64	4503	0.02	CHONDROSARCOMA (HUMERUS)
M015P01	536	9.67	0.00071	0.0263	OCT-23-64	4319	0.02	PANCREATIC DYSTROPHY
M016P01	501	12.0	0.00059	0.0218	APR-07-65	4146	0.02	EPIDERMOID CARC.(FRONTAL SINUS),SCIRRHOUS ADENOCARC.
M017P01	551	12.2	0.00057	0.0211	NOV-08-66	4346	0.02	LYMPHOSARCOMA
F018P01	536	9.78	0.00070	0.0259	NOV-29-66	4221	0.02	MELANOMA (MOUTH)
M019P01	536	11.6	0.00063	0.0233	NOV-29-66	5519	0.02	NEPHRITIS
F020P01	536	9.80	0.00075	0.0278	DEC-29-66	3939	0.02	MAMMARY ADENOCARCINOMA
M021P01	533	11.3	0.00059	0.0218	JAN-26-67	4675	0.02	LUNG CARCINOMA
F022P01	489	9.80	0.00059	0.0218	MAY-25-67	2968	0.01	ACCIDENTAL STRANGULATION
M031P01B	516	12.2	0.00068	0.0252	MAR-04-64	2760	0.01	STATUS EPILEPTICUS
F032P01B	549	10.4	0.00059	0.0218	NOV-18-65	5272	0.02	TRANS. CELL CARC.(URIN. BLADDER)GRANULOSA CELL TUMOR
M033P01B	549	10.8	0.00079	0.0292	NOV-18-65	4156	0.02	BONE MARROW APLASIA
F034P01B	533	11.1	0.00058	0.0215	NOV-08-66	3292	0.01	PANCREATITIS
M035P01B	489	10.3	0.00059	0.0218	MAY-25-67	5036	0.02	UNDIFFERENTIATED MALIGNANCY (ABDOMEN)
F036P01B	493	9.79	0.00060	0.0222	JUN-22-67	3600	0.02	PNEUMONIA
M037P01B	493	11.3	0.00059	0.0218	JUN-22-67	5072	0.02	ANKYLOSING SPONDYLITIS
F038P01B	513	9.52	0.00057	0.0211	DEC-21-67	1979	0.01	TRAUMA
M039P01B	490	10.5	0.00058	0.0215	DEC-21-67	4466	0.02	HEMANGIOSARCOMA (SOFT TISSUE)
M044P01B	500	10.9	0.00057	0.0211	AUG-08-73	4412	0.02	NEPHRITIS
F044P01C	569	8.34	0.00072	0.0266	DEC-02-70	4025	0.02	PULMONARY EMBOLISM, NEPHRITIS
M045P01B	504	13.5	0.00122	0.0451	MAY-30-74	3762	0.03	KIDNEY FAILURE,PNEUMONIA
F045P01C	500	9.00	0.00051	0.0189	AUG-08-73	5517	0.02	ABCESSATION (TOOTH)
M046P01B	504	13.2	0.00120	0.0444	MAY-30-74	3630	0.03	OBSTRUCTION (INTESTINE)

B.5 ^{239}Pu, Chronic Toxicity Study (continued)

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTION: INJECTED (UCI/KG)	INJECTION: INJECTED (KBQ/KG)	INJECTION: DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F046P01C	500	10.2	0.00057	0.0211	AUG-08-73	4409	0.02	ENDOMETRITIS,PERITONITIS
F047P01	500	9.34	0.00051	0.0189	AUG-08-73	4507	0.02	HEMANGIOSARCOMA (SOFT TISSUE)
F048P01	527	10.9	0.00120	0.0444	MAY-30-74	4858	0.04	PNEUMONIA (LUNG)
F049P01	504	9.71	0.00124	0.0459	MAY-30-74	3222	0.03	NEPHRITIS
F013P02	515	9.44	0.00206	0.0762	MAR-04-64	3221	0.05	ILEUS (INTESTINE)
F014P02	515	7.44	0.00173	0.0640	MAY-12-64	3983	0.05	ENTERITIS
M015P02	505	10.9	0.00201	0.0744	OCT-23-64	4803	0.07	ATHEROSCLEROSIS, ARTERIOSCLEROSIS
M016P02	500	11.4	0.00163	0.0603	APR-07-65	2841	0.04	ENCEPHALITIS
M017P02	553	11.8	0.00171	0.0633	NOV-08-66	4391	0.05	LYMPHOSARCOMA
F018P02	530	9.46	0.00200	0.0740	NOV-29-66	5319	0.07	NEPHRITIS
M019P02	530	12.1	0.00198	0.0733	NOV-29-66	4392	0.06	UNDETERMINED (NO SKELETAL TUMOR)
F020P02	522	8.30	0.00224	0.0829	DEC-29-66	4299	0.07	THROMBOEMBOLISM
M021P02	538	12.1	0.00181	0.0670	JAN-26-67	4708	0.06	UNDETERMINED (NO TUMOR)
F022P02	485	8.30	0.00176	0.0651	MAY-25-67	4180	0.05	LYMPHOSARCOMA
M031P02B	515	10.7	0.00185	0.0685	MAR-04-64	2640	0.04	MELANOMA (MOUTH)
F031P02C	452	11.9	0.00169	0.0625	MAY-12-64	4971	0.06	THROMBOEMBOLISM
F031P02D	428	9.35	0.00186	0.0688	MAY-12-64	5378	0.07	METASTATIC MAST CELL TUMORS
M032P02B	549	13.6	0.00178	0.0659	NOV-18-65	3591	0.05	HEMANGIOSARCOMA (SOFT TISSUE)
F032P02C	494	10.1	0.00183	0.0677	FEB-04-65	3881	0.05	MAMMARY ADENOCARCINOMA,THROMBOEMBOLISM
F032P02D	490	8.04	0.00193	0.0714	FEB-04-65	5241	0.07	MAST CELL SARCOMA
M033P02B	513	14.5	0.00178	0.0659	NOV-18-65	2776	0.04	PNEUMONIA
F033P02C	549	12.5	0.00176	0.0651	NOV-18-65	4615	0.06	HEMORRHAGE (KIDNEY)
F033P02D	513	12.7	0.00178	0.0659	NOV-18-65	5068	0.06	RHABDOMYOSARCOMA
M034P02B	533	12.7	0.00170	0.0629	NOV-08-66	3934	0.05	PROSTATE ADENOCARCINOMA
F034P02C	533	11.5	0.00172	0.0636	NOV-08-66	4515	0.05	LUNG CARCINOMA
F034P02D	519	9.92	0.00167	0.0618	NOV-08-66	4552	0.05	NEPHRITIS
M035P02B	469	11.2	0.00173	0.0640	MAY-25-67	4359	0.05	LYMPHOSARCOMA, ENTERITIS, INANITION
F035P02C	507	10.5	0.00175	0.0648	JUN-22-67	2593	0.04	LUNG CARCINOMA
F035P02D	507	9.10	0.00175	0.0648	JUN-22-67	4330	0.05	ENDOMETRITIS,PERITONITIS,NEPHRITIS
M036P02B	479	12.9	0.00177	0.0655	MAY-25-67	5245	0.06	MYXOSARCOMA (LIVER)
F036P02C	493	10.4	0.00177	0.0655	JUN-22-67	3291	0.04	ENTERITIS
F036P02D	569	8.74	0.00146	0.0540	NOV-16-67	3351	0.04	LYMPHOSARCOMA, PERFORATION (INTESTINE)
M037P02B	529	13.6	0.00149	0.0551	NOV-16-67	2804	0.03	HEMANGIOSARCOMA (SOFT TISSUE)
F037P02C	529	10.1	0.00150	0.0555	NOV-16-67	4829	0.05	PNEUMONIA
F037P02D	529	7.14	0.00153	0.0566	NOV-16-67	4787	0.05	MAMMARY ADENOCARCINOMA
M038P02B	517	10.0	0.00152	0.0562	NOV-16-67	3546	0.04	PLASMA CELL SARCOMA (SOFT TISSUE & SKELETON)
F038P02C	502	7.95	0.00211	0.0781	DEC-21-67	5006	0.07	DEGENERATION (LIVER),MAMMARY ADENOCARCINOMA
F038P02D	498	9.08	0.00176	0.0651	DEC-21-67	2880	0.04	NEPHRITIS,PANCREATITIS
M039P02B	542	11.6	0.00214	0.0792	DEC-02-70	2916	0.05	HEMANGIOSARCOMA (SOFT TISSUE)
F039P02C	498	9.46	0.00173	0.0640	DEC-21-67	4911	0.06	HEPATIC CELL CARCINOMA
F039P02D	498	9.34	0.00176	0.0651	DEC-21-67	3401	0.05	RHABDOMYOSARCOMA
M042P02B	504	9.42	0.00182	0.0673	AUG-08-73	4752	0.06	CHRONIC INTERSTITIAL NEPHRITIS
F042P02C	589	9.55	0.00176	0.0651	SEP-04-69	3966	0.05	OSTEOSARCOMA,VAGINA ADENOCARCINOMA
M043P02B	497	11.0	0.00179	0.0662	APR-24-74	4620	0.06	ADENOCARCINOMA (NASAL) TRACHEITIS

B.5 ^{239}Pu, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F043P02C	542	9.50	0.00239	0.0884	DEC-02-70	4942	0.08	MAMMARY ADENOCARCINOMA
M044P02B	540	11.6	0.00177	0.0655	NOV-17-71	97	0.01	SPECIAL STUDY
M044P02C	491	12.0	0.00188	0.0696	APR-24-74	5069	0.07	MELANOMA (ORAL CAVITY)
M044P02D	488	11.6	0.00184	0.0681	APR-24-74	4457	0.06	KIDNEY FAILURE,ADRENAL HYPOPLASIA
M045P02B	488	11.6	0.00184	0.0681	APR-24-74	3631	0.05	PARALYSIS (CERVICAL SPONDYLOSIS)
M045P02C	482	11.4	0.00188	0.0696	APR-24-74	5735	0.07	GLOMERULONEPHRITIS
M046P02B	482	11.1	0.00179	0.0662	APR-24-74	2624	0.04	UNDIFFERENTIATED MALIGNANCY (SOFT TISSUE)
F013P05	516	9.93	0.00540	0.200	MAR-04-64	2388	0.11	MAMMARY ADENOCARCINOMA
F013P05A	501	11.2	0.00495	0.183	SEP-23-70	3498	0.13	MAMMARY ADENOCARCINOMA
F014P05	516	9.98	0.00493	0.182	MAY-12-64	4537	0.16	CHONDROSARCOMA (TURBINATES + HUMERUS)
M015P05	505	8.41	0.00627	0.232	OCT-23-64	4588	0.20	THROMBOEMBOLISM,THYROID CARCINOMA
M016P05	501	12.6	0.00521	0.193	APR-07-65	4062	0.15	CHROMOPHOBE ADENOMA
M017P05	533	13.4	0.00506	0.187	NOV-08-66	4564	0.16	ANKYLOSIING SPONDYLITIS
F018P05	530	8.98	0.00594	0.220	NOV-29-66	4333	0.18	HEMANGIOSARCOMA (SOFT TISSUE)
M019P05	530	11.9	0.00645	0.239	NOV-29-66	3829	0.18	OSTEOSARCOMA
F020P05	532	9.30	0.00553	0.205	DEC-29-66	3490	0.14	EPIDERMOID CARCINOMA (MOUTH)
M021P05	538	9.80	0.00526	0.195	JAN-26-67	4954	0.18	DEGENERATION (KIDNEY),HEMORRHAGE (HYPOTHALAMUS)
F022P05	485	8.10	0.00525	0.194	MAY-25-67	5203	0.19	ANKYLOSING SPONDYLITIS,PNEUMONIA
M025P05	509	9.70	0.00539	0.199	JAN-30-74	4807	0.18	CHROMOPHOBE ADENOMA,SENILITY
M026P05	509	9.96	0.00536	0.198	JAN-30-74	4062	0.16	PNEUMONIA
M031P05B	515	10.5	0.00549	0.203	MAR-04-64	1648	0.08	STATUS EPILEPTICUS
F031P05C	494	8.44	0.00572	0.212	FEB-04-65	2546	0.12	SPECIAL STUDY
M032P05B	549	13.6	0.00546	0.202	NOV-18-65	2275	0.10	SPECIAL STUDY
F033P05B	503	10.1	0.00559	0.207	NOV-18-65	4509	0.18	MAMMARY CARCINOMA
M034P05B	530	12.5	0.00642	0.238	NOV-29-66	1981	0.11	SPECIAL STUDY
F035P05B	501	9.54	0.00520	0.192	JUN-22-67	4502	0.17	LUNG CARCINOMA
M036P05B	479	11.5	0.00527	0.195	MAY-25-67	3885	0.15	OSTEOSARCOMA
F037P05B	517	8.39	0.00454	0.168	NOV-16-67	4956	0.16	EPIDERMOID CARCINOMA (MOUTH)
M038P05B	517	10.5	0.00448	0.166	NOV-16-67	3498	0.12	UNDETERMINED (NO SKELETAL TUMOR)
F039P05B	490	10.9	0.00528	0.195!	DEC-21-67	4350	0.16	PERITONITIS,MAMMARY CARCINOMA
M042P05B	542	13.1	0.00675	0.250	DEC-02-70	4194	0.20	INANITION
M042P05C	542	12.2	0.00668	0.247	DEC-02-70	4778	0.22	PNEUMONIA
F042P05D	542	9.71	0.00668	0.247	DEC-02-70	3618	0.18	SURGICAL COMPLICATIONS
F043P05B	545	11.6	0.00484	0.179	OCT-03-69	4177	0.15	ENDOMETRITIS
F043P05C	537	10.7	0.00480	0.178	OCT-03-69	4393	0.15	TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
M043P05D	500	12.0	0.00546	0.202	AUG-08-73	5690	0.21	CHRONIC INTERSTITIAL PNEUMONIA
M044P05B	445	11.5	0.00360	0.133	JUN-03-69	99	0.01	SPECIAL STUDY
F044P05C	504	8.48	0.00604	0.223	AUG-08-73	4279	0.18	LUNG ABSCESS,LIVER DEGENERATION
M045P05B	472	10.3	0.00350	0.130	JUN-03-69	42	0.01	SPECIAL STUDY
F045P05C	540	10.0	0.00516	0.191	NOV-17-71	35	0.01	SPECIAL STUDY
M046P05B	484	11.8	0.00336	0.124	JUN-03-69	7	0.01	SPECIAL STUDY
F046P05C	540	9.15	0.00516	0.191	NOV-17-71	7	0.01	SPECIAL STUDY
M047P05	568	11.9	0.00524	0.194	AUG-08-74	2302	0.10	ABSCESS (LUNG),EMPYEMA
M048P05	568	12.1	0.00546	0.202	AUG-08-74	4809	0.18	INTERVERTEBRAL DISC PROLAPSE

B.5 ^{239}Pu, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F049P05	569	9.10	0.00537	0.199	AUG-08-74	3240	0.13	ENDOMETRITIS
F050P05	568	12.8	0.00541	0.200	AUG-08-74	4576	0.17	KIDNEY FAILURE
M051P05	506	11.9	0.00552	0.204	AUG-29-74	4272	0.17	THROMBOEMBOLISM (PORTAL VEIN)
M052P05	506	10.4	0.00549	0.203	AUG-29-74	3205	0.13	FIBROSARCOMA (SOFT TISSUE)
M053P05	498	13.2	0.00515	0.191	AUG-29-74	4004	0.15	OSTEOSARCOMA
M054P05	497	10.8	0.00551	0.204	AUG-29-74	2478	0.11	PNEUMONIA,EMPYEMA
F055P05	533	9.65	0.00547	0.202	OCT-17-74	2943	0.13	ACUTE PNEUMONITIS
F056P05	533	9.56	0.00552	0.204	OCT-17-74	2917	0.13	INANITION
F057P05	523	8.14	0.00524	0.194	OCT-17-74	4166	0.16	AORTIC BODY CARCINOMA,DEGENERATION (LIVER)
F101P05Y	93	2.74	0.00617	0.228	SEP-19-74	4207	0.13	ADENOCARCINOMA
M102P05Y	91	3.43	0.00618	0.229	SEP-19-74	5796	0.18	NEPHROSCLEROSIS; CHOLANGIOCARCINOMA, LIVER
F103P05Y	91	3.39	0.00611	0.226	SEP-19-74	4815	0.15	INANITION
M104P05Y	90	3.43	0.00525	0.194	APR-27-76	4222	0.11	AMYLOIDOSIS (KIDNEY),ADENOCARCINOMA (PITUITARY)
M105P05Y	89	4.17	0.00570	0.211	NOV-26-74	2787	0.08	ENTERITIS
F106P05Y	89	4.51	0.00580	0.215	NOV-26-74	4284	0.12	GRANULOSA CELL CARCINOMA
F107P05Y	94	5.53	0.00553	0.205	SEP-22-76	5486		LIVING
M108P05Y	91	4.47	0.00484	0.179	DEC-16-75	1793	0.05	DEGENERATION (PANCREAS)
F109P05Y	88	3.95	0.00542	0.201	APR-20-78	4911		LIVING
M110P05Y	90	4.48	0.00521	0.193	MAR-09-78	4863	0.13	LYMPHOSARCOMA
F111P05Y	88	3.67	0.00533	0.197	MAY-23-78	4878		LIVING
F014P07	533	8.98	0.00947	0.350	JUL-22-69	4746	0.31	PNEUMONIA
M015P07	533	10.3	0.00941	0.348	JUL-22-69	3471	0.24	CHONDROSARCOMA (SKELETAL,TURBINATES)
M016P07	516	11.9	0.0102	0.377	SEP-04-69	3573	0.27	HEPATITIS
M017P07	540	8.84	0.0103	0.381	OCT-03-69	3938	0.30	TRANSITIONAL CELL CARCINOMA, CHROMOPHOBE ADENOMA
F018P07	531	9.66	0.00942	0.349	JUL-22-69	4823	0.32	NEPHRITIS,DEGENERATION (LIVER)
M019P07	501	11.6	0.0104	0.385	SEP-23-70	1737	0.16	STRANGULATED HERNIA
F020P07	521	9.18	0.00926	0.343	JUL-22-69	3718	0.25	FIBROSARCOMA (LIVER)
M021P07	499	11.1	0.0104	0.385	SEP-23-70	5212	0.37	GLAUCOMA,SENILITY
F022P07	538	9.69	0.0103	0.400	SEP-04-69	4657	0.35	UNDETERMINED (NO TUMOR)
F023P07	538	9.56	0.0108	0.400	SEP-04-69	4481	0.34	OSTEOSARCOMA,PNEUMONIA
F024P07	516	8.90	0.0110	0.407	SEP-04-69	3861	0.31	OSTEOSARCOMA
M025P07	506	10.9	0.0117	0.433	AUG-08-73	2042	0.20	STATUS EPILEPTICUS
M026P07	494	10.2	0.0112	0.414	SEP-20-73	4023	0.33	OSTEOSARCOMA
M027P07	494	11.9	0.0116	0.429	SEP-20-73	5598	0.44	CHRONIC INTERSTITIAL NEPHRITIS/BRONCHIOLOALVEOLAR CARC
F028P07	494	10.6	0.0110	0.407	SEP-20-73	4512	0.35	BILIARY OBSTRUCTION,SUPPURATIVE CHOLANGIOHEPATITIS
F029P07	493	8.63	0.0113	0.418	SEP-20-73	4210	0.34	PHEOCHROMOCYTOMA
F030P07	487	9.91	0.0113	0.418	SEP-20-73	4246	0.34	OSTEOSARCOMA,MYOPROLIFERATIVE DISEASE
M031P07	521	13.2	0.00956	0.354	DEC-04-73	4253	0.29	LYMPHOSARCOMA
M032P07	521	9.46	0.00967	0.358	DEC-04-73	3496	0.25	PROSTATITIS,PERITONITIS
M033P07	569	10.7	0.0103	0.381	JAN-30-74	4807	0.35	KIDNEY FAILURE,PNEUMONIA
M034P07	521	10.1	0.00979	0.362	DEC-04-73	3711	0.27	THROMBOEMBOLISM
F035P07	521	10.6	0.00981	0.363	DEC-04-73	3661	0.27	PANCREATITIS,DIABETES MELLITUS
F036P07	521	11.1	0.00999	0.370	DEC-04-73	3951	0.29	PANCREATITIS
M037P07	520	11.6	0.00999	0.370	DEC-04-73	2836	0.22	FIBROSIS (LUNG),HEMANGIOSARCOMA (SOFT TISSUE)

B.5 ^{239}Pu, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F038P07	520	11.4	0.00995	0.368	DEC-04-73	4235	0.30	UNDETERMINED (NO SKELETAL TUMOR)
F039P07	512	8.24	0.00969	0.359	DEC-04-73	4795	0.32	KIDNEY FAILURE
M040P07	512	10.7	0.00990	0.366	DEC-04-73	4074	0.29	ADENOCARCINOMA (RECTUM)
M041P07	533	11.9	0.0105	0.389	JAN-30-74	2750	0.23	DEGENERATION (KIDNEY)
M042P07	533	11.6	0.0106	0.392	JAN-30-74	4235	0.32	THROMBOEMBOLISM
M043P07	533	10.1	0.0106	0.392	JAN-30-74	4942	0.36	OSTEOSARCOMA,CARCINOMA (LUNG)
F044P07	533	10.2	0.0105	0.389	JAN-30-74	4285	0.32	AMYLOID.(KID.),TR. CELL CARC.(BLADDER),THY. ADENOCARC.
M045P07	509	10.8	0.0104	0.385	JAN-30-74	4362	0.32	OSTEOSARCOMA,SEMINOMA
F046P07	509	10.2	0.0105	0.389	JAN-30-74	4655	0.34	TRANSITIONAL CELL CARCINOMA
F047P07	508	8.39	0.0103	0.381	JAN-30-74	5422	0.38	CHRONIC INTERSTITIAL NEPHRITIS/CELLULITIS
M048P07	502	10.3	0.00910	0.337	MAR-05-74	4735	0.30	PNEUMONIA
M049P07	471	12.3	0.00990	0.366	MAR-05-74	3405	0.25	UNDETERMINED (NO TUMOR)
F050P07	522	9.33	0.0112	0.414	AUG-29-74	4030	0.33	OSTEOSARCOMA
F051P07	522	11.8	0.0105	0.389	AUG-29-74	5594	0.40	HEPATIC NECROSIS AND REGENERATION
M001P10	442	9.41	0.0150	0.555	DEC-01-52	4572	0.48	OSTEOSARCOMA
F002P10	422	6.85	0.0163	0.603	MAR-02-53	4810	0.55	HEPATIC CELL CARCINOMA
M003P10	515	8.00	0.0165	0.611	JUN-01-53	4292	0.51	OSTEOSARCOMA
M004P10	608	9.97	0.0139	0.514	SEP-16-53	4549	0.45	CHOLANGIOCARCINOMA
F005P10	620	8.80	0.0142	0.525	OCT-14-53	1539	0.20	COLITIS,ENTERITIS,DEGENERATION (LIVER)
F005P10A	472	11.0	0.0168	0.622	SEP-03-58	3764	0.47	THYROID CARCINOMA
F006P10	409	7.38	0.0140	0.518	MAY-12-54	4292	0.43	COLON CARCINOMA
F007P10	510	6.36	0.0167	0.618	OCT-25-54	3981	0.48	TRAUMA,LYMPHADENOPATHY
M008P10	453	10.6	0.0172	0.636	MAR-15-55	3367	0.44	OSTEOSARCOMA
F009P10	555	7.87	0.0168	0.622	SEP-09-55	2257	0.32	OSTEOSARCOMA
F010P10	641	12.0	0.0152	0.562	NOV-22-55	3649	0.41	MAMMARY ADENOCARCINOMA
M011P10	602	8.90	0.0157	0.581	APR-24-56	5161	0.56	THYROID CARCINOMA
M012P10	629	9.67	0.0167	0.618	MAY-29-56	2374	0.33	PANCREATITIS
M013P10	504	12.7	0.0153	0.566	SEP-03-58	5277	0.55	SENILITY,HYDROCEPHALUS
F014P10	533	10.4	0.0141	0.522	JUL-22-69	4185	0.42	SURGICAL COMPLICATIONS
M015P10	516	12.8	0.0159	0.588	SEP-04-69	3596	0.42	MELANOMA (MOUTH)
M016P10	516	10.6	0.0165	0.611	SEP-04-69	4211	0.50	OSTEOSARCOMA
M017P10	537	10.9	0.0151	0.559	OCT-03-69	4690	0.50	CHONDROSARCOMA (TURBINATES)
F018P10	531	9.89	0.0140	0.518	JUL-22-69	4788	0.47	OVARY ADENOCARCINOMA
M019P10	501	9.82	0.0159	0.588	SEP-23-70	5217	0.57	CARCINOMA (SERT. CELLS)
F020P10	521	10.4	0.0141	0.522	JUL-22-69	3482	0.37	TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
M021P10	499	10.0	0.0156	0.577	SEP-23-70	3734	0.43	OSTEOSARCOMA
F022P10	571	9.04	0.0139	0.514	JUL-22-69	4035	0.41	OSTEOSARCOMA
F023P10	538	11.2	0.0163	0.603	SEP-04-69	4508	0.52	CHROMAPHOBE ADENOMA
F024P10	516	10.4	0.0163	0.603	SEP-04-69	3308	0.41	OSTEOSARCOMA
M025P10	504	11.0	0.0168	0.622	AUG-08-73	4793	0.56	HEMANGIOSARCOMA (NON-SKELETAL)
F101P10Y	93	2.23	0.0171	0.633	SEP-19-74	4636	0.39	THROMBOEMBOLISM (PULMONARY)
M102P10Y	91	2.83	0.0171	0.633	SEP-19-74	3549	0.31	PARALYSIS (SPONDILITIS)
F103P10Y	89	3.56	0.0137	0.507	NOV-21-74	1929	0.14	PERSISTENT AORTIC ARCH
M104P10Y	89	5.14	0.0158	0.585	NOV-21-74	3789	0.30	THROMBOEMBOLISM

B.5 ^{239}Pu, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION: AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M105P10Y	91	5.19	0.0143	0.529	MAR-02-76	4143	0.30	RHABDOMYOSARCOMA
F106P10Y	91	4.36	0.0142	0.525	MAR-02-76	5417	0.38	CARCINOMA,PITUITARY
F107P10Y	92	4.46	0.0194	0.718	OCT-08-76	5333	0.51	BILIARY CYSTS
F108P10Y	90	2.52	0.0146	0.540	DEC-16-76	5401		LIVING
M109P10Y	90	3.78	0.0155	0.574	MAR-09-78	4918	0.38	MAST CELL TUMOR,SKIN
M110P10Y	88	3.77	0.0158	0.585	MAY-23-78	4878		LIVING
F501P10+	1787	9.54	0.0158	0.585	JUN-10-75	3752	0.42	FIBROSARC.(SOFT TIS),MAMM. ADENOCARC. CHOLANGIOCARC.
F502P10+	1830	11.4	0.0174	0.644	JUL-06-77	2990	0.40	OSTEOSARCOMA,FIBROSARCOMA (SKELETON)
F503P10+	1855	9.76	0.0163	0.603	MAY-09-78	3381	0.40	FIBROSARCOMA (ORAL)
M507P10+	1481	13.3	0.0158	0.585	MAY-09-78	4028	0.44	CHOLANGIOCARCINOMA
M001P17	657	8.72	0.0475	1.76	JUN-26-56	3025	1.11	OSTEOSARCOMA
F002P17	527	8.62	0.0431	1.59	NOV-22-55	3430	1.11	OSTEOSARCOMA
M003P17	642	8.53	0.0495	1.83	JUN-26-56	3430	1.28	CHROMOPHOBE CARC.,BIL. OBSTRUCTION,PROS. ADENOCARC.
M004P17	673	8.37	0.0484	1.79	OCT-10-56	3312	1.22	OSTEOSARCOMA
F005P17	642	11.6	0.0493	1.82	JUN-26-56	2659	1.05	OSTEOSARCOMA
F006P17	642	10.3	0.0459	1.70	JUN-26-56	2221	0.86	OSTEOSARCOMA
F007P17	756	9.73	0.0481	1.78	OCT-10-56	3353	1.22	CHONDROSARCOMA
M008P17	673	13.6	0.0479	1.77	OCT-10-56	3282	1.19	OSTEOSARCOMA
F009P17	756	9.72	0.0485	1.79	OCT-10-56	2500	0.99	OSTEOSARCOMA
F010P17	739	10.6	0.0495	1.83	OCT-10-56	467	0.27	ENTERITIS
F010P17A	472	8.07	0.0457	1.69	SEP-03-58	4214	1.38	OSTEOSARCOMA
M011P17	599	11.6	0.0486	1.80	APR-24-56	2777	1.07	CHOLANGIOCARCINOMA
M012P17	673	9.41	0.0491	1.82	OCT-10-56	2973	1.14	LYMPHOSARCOMA
M013P17	504	10.6	0.0473	1.75	SEP-03-58	4375	1.47	CHONDROSARCOMA, OSTEOSARCOMA
F101P17Y	93	2.34	0.0543	2.01	SEP-19-74	4834	1.30	CARDIOMYOPATHY (HEART),CHOLANGIOCARCINOMA (LIVER)
M102P17Y	91	2.97	0.0545	2.02	SEP-19-74	3604	0.99	HEPATITIS
F103P17Y	89	3.84	0.0453	1.68	NOV-21-74	3912	0.89	TRANSITIONAL CELL CARC.(URINARY BLADDER),NEPHROSIS
M104P17Y	93	3.40	0.0438	1.61	APR-27-76	5634		LIVING
M105P17Y	90	4.06	0.0485	1.79	APR-27-76	4014	0.97	THROMBOEMBOLISM (AORTA)
F106P17Y	89	4.20	0.0529	1.96	NOV-26-74	3885	1.03	OSTEOSARCOMA,CHOLANGIOCARCINOMA
F107P17Y	93	3.91	0.0477	1.76	SEP-24-76	2997	0.73	PERFORATION (INTESTINE)
M108P17Y	92	4.32	0.0473	1.75	OCT-08-76	5470		LIVING
F109P17Y	88	3.06	0.0510	1.89	APR-20-78	4457	1.13	ADENOCARCINOMA, COLON
M110P17Y	92	3.07	0.0464	1.72	JUL-11-78	4829		LIVING
F111P17Y	92	3.02	0.0471	1.74	JUL-11-78	4829		LIVING
F501P17+	1725	10.0	0.0456	1.69	JUN-24-75	2163	0.82	MAMMARY ADENOCARCINOMA
F502P17+	1732	10.0	0.0416	1.54	DEC-16-75	3771	1.11	OSTEOSARCOMA,THROMBOEMBOLISM
F503P17+	1826	10.2	0.0519	1.92	MAY-13-76	3502	1.32	THROMBOEMBOLISM,(KIDNEY) AMYLOIDOSIS
F504P17+	1831	11.2	0.0527	1.95	JUL-06-77	3337	1.29	MAMMARY ADENOCARCINOMA
F505P17+	1846	9.96	0.0441	1.63	MAY-09-78	2577	0.90	OSTEOSARCOMA
F506P17+	1823	9.56	0.0449	1.66	MAY-09-78	3803	1.20	BRONCHOPNEUMONIA
M507P17+	1849	10.7	0.0458	1.69	JUL-20-78	3011	1.05	OSTEOSARCOMA
M508P17+	1840	12.6	0.0430	1.59	SEP-07-78	3452	1.08	OSTEOSARCOMA (FEMUR)
M509P17+	1845	12.7	0.0498	1.84	NOV-30-78	2160	0.91	HEPATITIS

B.5 ^{239}Pu, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M510P17+	1835	11.5	0.0503	1.86	NOV-30-78	2002	0.85	OSTEOSARCOMA
M001P20	442	7.61	0.0853	3.16	DEC-01-52	2985	1.98	OSTEOSARCOMA
F002P20	422	7.73	0.112	4.14	MAR-02-53	2780	2.47	OSTEOSARCOMA
M003P20	485	10.5	0.0940	3.48	JUN-01-53	3185	2.29	OSTEOSARCOMA
M004P20	608	9.84	0.0862	3.19	SEP-16-53	2948	1.98	OSTEOSARCOMA
F005P20	594	8.12	0.0846	3.13	OCT-14-53	2423	1.68	OSTEOSARCOMA
F006P20	417	7.54	0.0902	3.34	MAY-12-54	2947	2.07	OSTEOSARCOMA
F007P20	485	8.40	0.0996	3.69	OCT-25-54	2093	1.78	EPIDERMOID CARCINOMA (FRONTAL SINUS)
M008P20	406	9.73	0.0957	3.54	MAR-15-55	1761	1.50	PNEUMONIA
F009P20	552	9.72	0.101	3.74	SEP-09-55	2014	1.75	OSTEOSARCOMA
F010P20	551	7.94	0.0968	3.58	NOV-22-55	2912	2.21	OSTEOSARCOMA
M011P20	599	10.3	0.0961	3.56	APR-24-56	1617	1.42	OSTEOSARCOMA
M012P20	622	9.98	0.100	3.70	MAY-29-56	2284	1.90	OSTEOSARCOMA
F101P20Y	91	2.60	0.0981	3.63	SEP-19-74	4900	2.37	OSTEOSARCOMA (FEMUR)
M102P20Y	91	2.85	0.106	3.92	SEP-19-74	4078	2.16	AMYLOIDOSIS (KIDNEY)
M103P20Y	93	4.27	0.0904	3.34	MAR-02-76	4370	1.96	CHOLANGIOCARCINOMA (LIVER),AMYLOIDOSIS (KIDNEY)
F104P20Y	92	3.12	0.0904	3.34	APR-13-76	5097	2.27	CHOLANGIOCARCINOMA, LIVER
M105P20Y	90	4.10	0.0963	3.56	APR-27-76	4146	1.99	OSTEOSARCOMA
F106P20Y	91	2.81	0.0961	3.56	APR-27-76	3117	1.53	OSTEOSARCOMA
F107P20Y	94	3.22	0.0980	3.63	SEP-22-76	4100	2.01	AMYLOIDOSIS (KIDNEY)
M108P20Y	91	3.69	0.0834	3.09	DEC-16-76	4957	2.04	CHONDROBLASTIC OSTEOSARCOMA, HUMERUS
F109P20Y	88	2.60	0.0921	3.41	MAY-09-78	2654	1.27	MYXOSARCOMA (LIVER)
M110P20Y	92	3.28	0.0929	3.44	JUL-11-78	2890	1.38	PARALYSIS (UNDETERMINED)
F111P20Y	92	3.18	0.0958	3.54	JUL-11-78	4430	2.11	GIANT CELL TUMOR, TIBIA
F501P20+	1787	10.2	0.0903	3.34	JUN-10-75	2288	1.69	OSTEOSARCOMA
F502P20+	1757	10.2	0.0908	3.36	MAR-05-76	1715	1.36	THROMBOEMBOLISM
F503P20+	1743	8.44	0.110	4.07	MAR-05-76	1879	1.77	OSTEOSARCOMA,THROMBOEMBOLISM
F504P20+	1874	8.87	0.0922	3.41	JUL-20-78	3305	2.25	UNDETERMINED
F505P20+	1855	7.60	0.0942	3.49	JUL-20-78	1623	1.35	PHEOCHROMOCYTOMA
F506P20+	1887	7.95	0.0923	3.42	SEP-07-78	2002	1.56	UNDETERMINED (NO TUMOR)
M507P20+	1855	11.8	0.0911	3.37	JUL-20-78	2253	1.69	LYMPHOSARCOMA
M508P20+	1817	7.91	0.0917	3.39	SEP-07-78	2399	1.78	FIBROSARCOMA (SKELETON),CHOLANGIOCARCINOMA
M509P20+	1835	10.6	0.0979	3.62	NOV-30-78	2559	1.99	OSTEOSARCOMA
M510P20+	1794	12.0	0.0988	3.66	NOV-30-78	1728	1.49	NEPHRITIS,THROMBOEMBOLISM
M001P30	418	8.00	0.261	9.66	DEC-01-52	1476	4.25	OSTEOSARCOMA
F002P30	422	6.85	0.312	11.5	MAR-02-53	1947	6.50	OSTEOSARCOMA
M003P30	485	8.74	0.291	10.8	JUN-01-53	1604	5.10	OSTEOSARCOMA
M004P30	608	8.51	0.292	10.8	SEP-16-53	1950	6.09	OSTEOSARCOMA
F005P30	650	8.22	0.288	10.7	OCT-14-53	1504	4.77	OSTEOSARCOMA
F006P30	415	8.38	0.282	10.4	MAY-12-54	1617	4.98	OSTEOSARCOMA
F007P30	485	9.00	0.314	11.6	OCT-25-54	1627	5.58	OSTEOSARCOMA

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F502P20 AND F503P20 WERE GIVEN TRACER 8.88 KBQ (0.24 UCI) PU-237 IN THE SAME INJECTION SOLUTION CONTAINING THEIR PU-239.

B.5 ^{239}Pu, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M008P30	406	9.73	0.300	11.1	MAR-15-55	1771	5.75	OSTEOSARCOMA
F009P30	552	7.67	0.300	11.1	SEP-09-55	1894	6.10	OSTEOSARCOMA
F010P30	533	8.94	0.298	11.0	NOV-22-55	1546	5.06	OSTEOSARCOMA
M011P30	599	10.5	0.309	11.4	APR-24-56	1198	4.17	OSTEOSARCOMA
M012P30	622	10.2	0.308	11.4	MAY-29-56	1659	5.57	OSTEOSARCOMA
M081P30Y	91	4.03	0.320	11.8	APR-25-72	2590	4.31	MYXOSARCOMA (SKELETON)
M086P30Y	89	3.29	0.319	11.8	APR-25-72	3368	5.44	CHOLANGIOSARCOMA PROSTATITIS
M089P30Y	89	4.23	0.312	11.5	APR-25-72	2942	4.71	OSTEOSARCOMA
F101P30Y	91	2.88	0.332	12.3	SEP-19-74	2290	4.01	FIBROSARCOMA (LIVER)
M102P30Y	93	3.93	0.316	11.7	APR-27-76	2935	4.76	OSTEOSARCOMA
F103P30Y	92	3.54	0.269	9.95	APR-13-76	2410	3.40	OSTEOSARCOMA
M104P30Y	92	4.65	0.317	11.7	APR-27-76	2564	4.23	OSTEOSARCOMA
M105P30Y	91	3.86	0.312	11.5	APR-27-76	2101	3.49	OSTEOSARCOMA
F106P30Y	91	4.22	0.315	11.7	JUN-01-76	2692	4.39	OSTEOSARCOMA
F107P30Y	93	3.69	0.295	10.9	SEP-24-76	2666	4.07	OSTEOSARCOMA
M108P30Y	90	3.56	0.283	10.5	DEC-16-76	1873	2.87	BILIARY OBSTRUCTION
F109P30Y	88	2.78	0.300	11.1	MAY-09-78	2906	4.48	OSTEOSARCOMA
F501P30+	1718	10.3	0.290	10.7	JUN-17-75	1634	4.19	OSTEOSARCOMA
F502P30+	1739	9.56	0.298	11.0	DEC-23-75	1456	3.92	OSTEOSARCOMA
F503P30+	1887	10.9	0.273	10.1	SEP-07-78	1538	3.75	OSTEOSARCOMA
F504P30+	1843	9.09	0.318	11.8	NOV-30-78	1078	3.25	NEPHRITIS
F505P30+	1835	8.19	0.312	11.5	NOV-30-78	1419	4.02	OSTEOSARCOMA
F506P30+	1823	7.55	0.274	10.1	SEP-07-78	364	1.05	SURGICAL COMPLICATIONS
M507P30+	1853	11.8	0.274	10.1	SEP-07-78	1421	3.53	OSTEOSARCOMA
M508P30+	1829	10.2	0.304	11.2	NOV-02-78	1545	4.20	OSTEOSARCOMA
M509P30+	1817	11.6	0.306	11.3	NOV-02-78	1066	3.10	OSTEOSARCOMA
M510P30+	1794	11.1	0.313	11.6	NOV-30-78	1706	4.68	OSTEOSARCOMA
M001P40	442	7.61	0.823	30.5	DEC-01-52	1724	16.3	OSTEOSARCOMA
F002P40	568	8.65	1.03	38.1	MAR-02-53	1556	18.6	OSTEOSARCOMA
M003P40	485	9.36	0.929	34.4	JUN-01-53	1198	13.1	OSTEOSARCOMA
M004P40	566	8.74	0.974	36.0	SEP-16-53	1066	12.4	OSTEOSARCOMA
F005P40	650	7.05	0.872	32.3	OCT-14-53	1245	12.8	OSTEOSARCOMA
F006P40	420	9.26	0.811	30.0	MAY-12-54	1357	12.9	OSTEOSARCOMA
F007P40	485	8.45	0.963	35.6	OCT-25-54	1198	13.6	OSTEOSARCOMA
M008P40	651	9.22	0.887	32.8	MAR-15-55	1157	12.1	OSTEOSARCOMA
F009P40	552	8.58	0.960	35.5	SEP-09-55	1343	15.1	OSTEOSARCOMA
F010P40	527	6.48	0.868	32.1	NOV-22-55	1241	12.7	OSTEOSARCOMA
M011P40	596	9.56	0.927	34.3	APR-24-56	1288	14.0	OSTEOSARCOMA
M012P40	598	11.4	0.838	31.0	MAY-29-56	1463	14.3	OSTEOSARCOMA
M001P50	418	8.86	2.67	98.8	DEC-01-52	1324	43.3	OSTEOSARCOMA
F002P50	1150	8.75	3.30	122.	MAR-02-53	1576	54.7	OSTEOSARCOMA,CRIPPLING FRACTURE
M003P50	515	8.10	3.00	111.	JUN-01-53	499	19.0	DEGENERATION (LIVER),ASCITES
M004P50	566	9.18	3.17	117.	SEP-16-53	1562	60.2	OSTEOSARCOMA
F005P50	691	8.77	2.77	102.	OCT-14-53	2059	68.5	OSTEOSARCOMA,DEGENERATION,HEMORRHAGE (LIVER)

B.5 ^{239}Pu, Chronic Toxicity Study (continued)

	INJECTION							
DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F006P50	407	7.90	2.57	95.1	MAY-12-54	1194	37.7	OSTEOSARCOMA
F007P50	482	8.33	2.99	111.	OCT-25-54	1491	54.3	OSTEOSARCOMA,CRIPPLING FRACTURE
M008P50	497	9.55	2.69	99.5	MAR-15-55	1192	39.4	GINGIVITIS
F009P50	552	9.45	2.73	101.	SEP-09-55	1145	38.5	OSTEOSARCOMA,EPISTAXIS,CIRCULATORY FAILURE
M081P50Y	94	4.60	2.68	99.2	MAR-01-72	1161	22.1	OSTEOSARCOMA
F082P50Y	94	4.80	2.66	98.4	MAR-01-72	1295	23.9	OSTEOSARCOMA
F083P50Y	94	4.00	2.66	98.4	MAR-01-72	1442	26.2	OSTEOSARCOMA,FIBROSARCOMA (SOFT TISSUE)
F084P50Y	94	3.55	2.68	99.2	MAR-01-72	1259	23.6	OSTEOSARCOMA
F085P50Y	94	4.15	2.64	97.7	MAR-01-72	1134	21.3	OSTEOSARCOMA
M086P50Y	93	3.75	2.95	109.	APR-25-72	1345	27.4	OSTEOSARCOMA
F087P50Y	93	4.15	2.93	108.	APR-25-72	1119	23.4	OSTEOSARCOMA
F088P50Y	93	3.65	2.96	110.	APR-25-72	1227	25.5	OSTEOSARCOMA
M089P50Y	93	3.79	2.92	108.	APR-25-72	1443	28.7	OSTEOSARCOMA
M090P50Y	93	4.38	2.97	110.	APR-25-72	1137	24.0	OSTEOSARCOMA
M091P50Y	91	3.78	2.90	107.	APR-25-72	1491	29.3	OSTEOSARCOMA
M092P50Y	91	3.82	2.87	106.	APR-25-72	1616	31.03	OSTEOSARCOMA

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M042P00B WAS REMOVED FROM INJECTION TABLES BECAUSE DOG NEVER REACHED YOUNG ADULT AGE.

B.6 ^{224}Ra (Quickradium), Chronic Toxicity Study

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M001Q00H	458	11.6			MAY-19-77	2602		STATUS EPILEPTICUS
F002Q00H	647	10.7			MAY-19-77	3316		MAMMARY ADEONCARCINOMA
M003Q00H	646	10.4			NOV-30-77	2481		UNDETERMINED
F004Q00H	586	10.3			MAY-19-77	1244		PNEUMONIA
M005Q00H	646	11.3			NOV-30-77	4971		SYSTEMIC AMYLOIDOSIS
F006Q00H	586	9.58			MAY-19-77	4299		SYNOVIAL CELL SARCOMA
M041Q00	589	10.1			JAN-09-79	3544		MAST CELL SARCOMA, DISSEMINATED
F042Q00	[illegible]	9.48			MAY-02-79	4534		LIVING
M043Q00	[illegible]	9.95			SEP-12-78	4525		PANCREATITIS
F044Q00	[illegible]	7.82			MAY-02-79	3905		TRANSITIONAL CELL CARCINOMA, BLADDER
M045Q00	673	10.6			SEP-12-78	4766		LIVING
F046Q00	619	[illegible]			AUG-10-77	3819		CARCINOMA (MAMMARY)
M081Q00H	639	[illegible]			FEB-14-79	2498		MELANOMA (MOUTH)
F082Q00H	623	7.80			FEB-14-79	4611		LIVING
M083Q00H	639	9.17			FEB-14-79	4611		LIVING
F084Q00H	660	10.2			APR-25-79	3582		SOLID CACINOMA, MAMMARY GLAND
M085Q00H	660	10.5			APR-25-79	4306		CARCINOMA,NASAL CAVITY
F086Q00H	626	8.85			APR-25-79	4541		LIVING
M001Q20H	647	11.9	0.291	10.8	MAY-19-77	4668	0.09	INTERVERTEBRAL DISC DISEASE
F002Q20H	647	10.9	0.317	11.7	MAY-19-77	2944	0.10	ENDOMETRITIS
M003Q20H	635	9.62	0.359	13.3	MAY-19-77	2156	0.11	THROMBOEMBOLISM, PANCREATITIS
F004Q20H	635	8.18	0.423	15.7	MAY-19-77	5021	0.13	HYPERADRENOCORTICISM
M005Q20H	643	10.1	0.342	12.7	MAY-19-77	1309	0.10	CHRONIC PANCREATITIS
F006Q20H	632	9.82	0.352	13.0	MAY-19-77	1797	0.11	MAMMARY ADENOCARCINOMA
M007Q20H	683	10.9	0.317	11.7	MAY-19-77	4670	0.10	INTERVERTEBRAL DISC DISEASE
F008Q20H	647	11.1	0.312	11.5	MAY-19-77	3835	0.09	TRANSITIONAL CELL CARCINOMA, URINARY BLADDER
M009Q20H	610	11.4	0.303	11.2	MAY-19-77	4280	0.09	HEMATOMA, SPLEEN
F010Q20H	610	8.52	0.406	15.0	MAY-19-77	3143	0.12	HERNIATION (CERVICAL DISC)
M011Q20H	610	10.3	0.336	12.4	MAY-19-77	4666	0.10	NEUROFIBROSARCOMA, CECUM
F012Q20H	610	8.62	0.401	14.8	MAY-19-77	3648	0.12	THROMBOEMBOLISM, KIDNEY FAILURE
M041Q20	704	11.2	0.365	13.5	JAN-09-79	2268	0.11	HYDROCEPHALUS
F042Q20	662	9.78	0.352	13.0	DEC-05-78	4353	0.11	CARCINOMA,MAMMARY GLAND
M043Q20	687	9.22	0.355	13.1	JAN-09-79	4307	0.11	GLOMERULONEPHRITIS
F044Q20	687	7.99	0.359	13.3	JAN-09-79	4647		LIVING
M045Q20	621	9.15	0.344	12.7	DEC-05-78	4682		LIVING
F046Q20	687	10.8	0.362	13.4	JAN-09-79	4647		LIVING
M047Q20	636	11.1	0.343	12.7	NOV-30-77	2792	0.10	ADENOCARCINOMA (RECTUM)
F048Q20	603	8.05	0.356	13.2	JAN-09-79	4647		LIVING
M049Q20	646	12.2	0.348	12.9	NOV-30-77	3904	0.10	CHOLANGIOCARCINOMA (LIVER)
F050Q20	667	11.4	0.383	14.2	SEP-12-78	4026	0.11	PYOMETRA/SEPTICEMIA
M051Q20	636	10.7	0.348	12.9	NOV-30-77	2090	0.10	THROMBOEMBOLISM
F052Q20	619	11.2	0.344	12.7	AUG-10-77	3129	0.10	ADENOCARCINOMA (NASAL CAVITY)
M081Q20H	662	10.6	0.283	10.5	FEB-14-79	3381	0.08	CNS DISEASE, CAUSE UNDETERMINED
F082Q20H	639	8.68	0.345	12.8	FEB-14-79	3452	0.10	MELANOMA (SOFT PALATE)

B.6 ^{224}Ra (Quickradium), Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M083Q20H	594	8.10	0.370	13.7	FEB-14-79	2925	0.11	LYMPHOSARCOMA
F084Q20H	594	7.32	0.409	15.1	FEB-14-79	3187	0.12	GLOMERULONEPHRITIS (KIDNEY)
M085Q20H	590	9.23	0.325	12.0	FEB-14-79	3498	0.10	LYMPHOSARCOMA, DISSEMINATED
F086Q20H	583	8.28	0.362	13.4	FEB-14-79	4588	0.11	GLOMERULONEPHRITIS
M087Q20H	694	10.6	0.336	12.4	APR-25-79	3715	0.10	LYMPHOSARCOMA, SMALL INTESTINE
F088Q20H	626	9.59	0.372	13.8	APR-25-79	4488	0.10	MYELOPROLIFERATIVE DISEASE
M089Q20H	653	9.93	0.359	13.3	APR-25-79	4541		LIVING
F090Q20H	626	10.0	0.356	13.2	APR-25-79	4541		LIVING
M091Q20H	695	10.3	0.346	12.8	APR-25-79	3743	0.10	HEPATITIS
F092Q20H	596	7.91	0.450	16.7	APR-25-79	3711	0.14	TUBULAR ADENOCARCINOMA, MAMMARY GLAND
M001Q30H	647	10.3	1.06	39.2	MAY-19-77	3938	0.32	INTERVERTEBRAL DISC PROLAPSE, HEPATITIS (LIVER)
F002Q30H	647	10.4	1.05	38.8	MAY-19-77	3754	0.32	THROMBOEMBOLISM (PULMONARY)
M003Q30H	642	10.3	1.06	39.2	MAY-19-77	4576	0.32	LYMPHOSARCOMA
F004Q30H	643	8.16	1.33	49.2	MAY-19-77	2685	0.40	PANCREATIC ATROPHY, ENTERITIS
M005Q30H	632	11.8	0.922	34.1	MAY-19-77	4180	0.28	GASTROENTERITIS
F006Q30H	647	10.4	1.05	38.8	MAY-19-77	3632	0.32	OSTEOSARCOMA
M007Q30H	642	11.8	0.922	34.1	MAY-19-77	2862	0.28	INTUSSUSCEPTION (ILEUM)
F008Q30H	632	9.10	1.20	44.4	MAY-19-77	3716	0.36	THROMBOEMBOLISM, CHROMATOPHOBE ADENOMA
M009Q30H	666	13.4	0.822	30.4	MAY-19-77	3095	0.25	PNEUMONIA, CHRONIC ENTERITIS
F010Q30H	666	11.3	0.962	35.6	MAY-19-77	4338	0.29	TRANSITIONAL CARCINOMA, NASAL CAVITY
M011Q30H	610	10.5	1.04	38.5	MAY-19-77	4324	0.31	FIBROBLASTIC OSTEOSARCOMA, MAXILLA
F012Q30H	610	9.75	1.12	41.4	MAY-19-77	3855	0.34	LYMPHOSARCOMA, DISSEMINATED
M041Q30	671	9.98	1.10	40.7	DEC-05-78	4301	0.33	PYELONEPHRITIS
F042Q30	705	9.04	1.11	41.1	JAN-09-79	3508	0.33	MYELOFIBROSIS (BONE MARROW)
M043Q30	656	9.42	1.12	41.4	DEC-05-78	2154	0.34	PANCREATITIS, PNEUMONIA
F044Q30	688	8.42	1.11	41.1	JAN-09-79	4647		LIVING
M045Q30	704	11.3	1.15	42.6	JAN-09-79	4331	0.35	GLOMERULONEPHRITIS
F046Q30	687	9.68	1.15	42.6	JAN-09-79	2242	0.34	TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
M047Q30	656	10.2	1.14	42.2	JAN-09-79	4647		LIVING
F048Q30	687	8.95	1.12	41.4	JAN-09-79	4626	0.34	CARCINOMA,MAMMARY GLAND
M049Q30	630	9.58	1.12	41.4	NOV-30-77	4767	0.34	CARCINOMA,PANCREAS
F050Q30	572	9.40	1.21	44.8	SEP-12-78	4461	0.36	SYSTEMIC AMYLOIDOSIS
M051Q30	638	9.85	1.08	40.0	NOV-30-77	3731	0.32	HEMANGIOSARCOMA (HEART)
F052Q30	634	9.97	1.10	40.7	AUG-10-77	3182	0.33	ENDOMETRITIS
M081Q30H	657	12.1	0.720	26.6	FEB-14-79	4611		LIVING
F082Q30H	639	8.73	0.999	37.0	FEB-14-79	4611		LIVING
M083Q30H	664	8.28	1.05	38.8	FEB-14-79	2602	0.32	FIBROSARCOMA (SKELETON)
F084Q30H	594	6.77	1.29	47.7	FEB-14-79	4611		LIVING
M085Q30H	590	7.75	1.12	41.4	FEB-14-79	3852	0.34	PERITONITIS
F086Q30H	583	8.07	1.08	40.0	FEB-14-79	4296	0.32	GRANULOSA CELL TUMOR,OVARY
M087Q30H	664	9.11	1.11	41.1	APR-25-79	3009	0.33	SPONDYLOSIS DEFORMANS
F088Q30H	626	9.91	1.02	37.7	APR-25-79	3032	0.31	MYXOSARCOMA (ORAL)
M089Q30H	694	9.84	1.02	37.7	APR-25-79	4137	0.31	PAPILLARY ADENOCARCINOMA, LUNG
F090Q30H	626	8.55	1.18	43.7	APR-25-79	4095	0.35	HEMANGIOSARCOMA, SUBCUTIS

B.6 ^{224}Ra (Quickradium), Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M091Q30H	653	7.54	1.34	49.6	APR-25-79	3807	0.40	RENAL AMYLOIDOSIS
F092Q30H	607	8.95	1.13	41.8	APR-25-79	4541		LIVING
M001Q40H	653	10.2	3.23	120.	MAY-19-77	3563	0.97	EPIDERMOID CARCINOMA (ORAL)
F002Q40H	653	9.44	3.49	129.	MAY-19-77	1580	1.05	THORACIC EXTRAVASATION OF LYMPH, OVARIAN PAPILLARY CARCINOMA
M003Q40H	642	13.5	2.44	90.3	MAY-19-77	3637	0.73	HEMANGIOSARCOMA (ABDOMEN)
F004Q40H	643	9.10	3.62	134.	MAY-19-77	3787	1.09	OSTEOSARCOMA, METATARSUS
M005Q40H	643	10.5	3.14	116.	MAY-19-77	3235	0.94	ADENOCARCINOMA (NASAL CAVITY)
F006Q40H	647	10.8	3.05	113.	MAY-19-77	1923	0.92	MAMMARY ADENOCARCINOMA
M041Q40	607	10.9	3.04	112.	NOV-30-77	5052		LIVING
F042Q40	706	10.8	3.28	121.	JAN-09-79	4012	0.98	AUTOIMMUNE HEMOLYTIC ANEMIA
M043Q40	662	11.2	3.25	120.	DEC-05-78	4018	0.98	SQUAMOUS CELL CARCINOMA, MAXILLA
F044Q40	691	7.74	3.28	121.	JAN-09-79	4285	0.98	ODONTOAMELOBLASTOMA
M045Q40	630	10.2	3.28	121.	NOV-30-77	4615	0.98	OSTEOBLASTIC OSTEOSARCOMA, THORACIC VERTEBRA
F046Q40	674	8.85	3.56	132.	SEP-12-78	4766		LIVING
M081Q40H	657	11.0	2.90	107.	FEB-14-79	3224	0.87	HEMANGIOSARCOMA, ADRENAL GLAND
F082Q40H	639	8.80	3.62	134.	FEB-14-79	4611		LIVING
M083Q40H	608	10.6	3.01	111.	FEB-14-79	4611		LIVING
F084Q40H	678	10.4	3.01	111.	APR-25-79	3873	0.90	LEIOMYOFIBROSARCOMA, VAGINA
M085Q40H	664	8.25	3.80	141.	APR-25-79	2729	1.14	SPONDYLOSIS DEFORMANS
F086Q40H	688	9.37	3.35	124.	APR-25-79	4541		LIVING
M001Q50H	653	10.6	8.64	320.	MAY-19-77	2433	2.59	OSTEOSARCOMA
F002Q50H	653	11.4	8.04	297.	MAY-19-77	1994	2.41	OSTEOSARCOMA
M003Q50H	643	10.6	8.64	320.	MAY-19-77	2016	2.59	UNDETERMINED (NO SKELETAL TUMOR)
F004Q50H	647	8.35	11.0	406.	MAY-19-77	1636	3.29	OSTEOSARCOMA
M005Q50H	635	9.88	9.27	343.	MAY-19-77	2021	2.78	OSTEOSARCOMA
F006Q50H	647	9.12	10.0	370.	MAY-19-77	2259	3.00	OSTEOSARCOMA
M041Q50	705	11.4	9.65	357.	JAN-09-79	3742	2.90	FIBROSARCOMA, LIVER
F042Q50	671	7.76	10.2	377.	DEC-05-78	3066	3.06	OSTEOSARCOMA
M043Q50	697	9.41	9.59	355.	JAN-09-79	9	2.43	BLOOD DYSCRASIA
M043Q50A	722	11.2	10.3	381.	JUL-03-79	12	2.83	PURPURA HEMORRHAGICA
F044Q50	656	8.08	10.3	381.	DEC-05-78	16	3.02	PURPURA HEMORRHAGICA
F044Q50A	672	10.0	10.8	400.	JUL-10-79	2841	3.24	MAMMARY ADENOCARCINOMA
M045Q50	604	9.75	12.0	444.	DEC-07-77	3800	3.60	MYXOMA (OMENTUM & LIVER), OSTEOSARCOMA, VERTEBRA
F046Q50	656	8.22	9.64	357.	JAN-09-79	3591	2.89	TUBULAR ADENOCARCINOMA, MAMMARY GLAND
M081Q50H	618	8.37	10.0	370.	FEB-14-79	2878	3.00	OSTEOSARCOMA, THROMBOEMBOLISM AMYLOIDOSIS
F082Q50H	664	9.73	8.63	319.	FEB-14-79	2941	2.59	OSTEOSARCOMA
M083Q50H	618	9.00	9.33	345.	FEB-14-79	3422	2.80	CNS DISEASE, CAUSE UNDETERMINED
F084Q50H	678	11.2	9.93	367.	APR-25-79	2673	2.98	SPLENIC HEMORRHAGE, MAMMARY ADENOCARCINOMA
M085Q50H	678	11.7	9.50	352.	APR-25-79	2487	2.85	OSTEOSARCOMA
F086Q50H	660	11.6	9.59	355.	APR-25-79	972	2.88	FIBROSARCOMA

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GROUPS 41-52 RECEIVED RA-224 IN 1 INJECTION.
81-92 RECEIVED RA-224 IN 10 FRACTIONS (1/WEEK).
1-12 RECEIVED RA-224 IN 50 FRACTIONS (1/WEEK).

B.7 ^{226}Ra, Chronic Toxicity Study

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M001R00	558	8.03			APR-20-53	3116		SEMINOMA, LYMPHOSARCOMA
M002R00	487	14.6			NOV-16-53	3675		TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
F003R00	601	11.4			MAR-10-54	2139		STATUS EPILEPTICUS
M004R00	461	11.0			APR-07-54	5284		NEPHRITIS, THROMBOEMBOLISM
M005R00	460	6.57			JUN-22-54	4018		THROMBOEMBOLISM
F006R00	483	8.43			JUL-27-54	3182		STATUS EPILEPTICUS
M007R00	511	11.0			AUG-24-54	3360		STATUS EPILEPTICUS, NEPHRITIS
F008R00	638	8.21			DEC-21-54	3361		PANCREAS ADENOCARCINOMA
F009R00	700	11.7			APR-11-55	1550		AORTIC BODY TUMOR
M010R00	522	10.9			JUL-27-55	4698		NEPHRITIS
F011R00	544	10.2			DEC-20-55	4575		FIBROMA (VAGINA)
F012R00	501	8.68			JAN-17-56	4283		PNEUMONIA
M013R00	515	12.3			MAR-04-64	4752		MELANOMA (MOUTH)
F014R00	536	10.8			OCT-23-64	5725		THROMBOEMBOLISM, ISLET CELL TUMOR
M015R00	564	12.8			FEB-04-65	4372		PANCREATITIS, HYDROCEPHALUS
F016R00	469	10.0			APR-07-65	3677		EPIDERMOID CARCINOMA (LUNG)
M017R00	469	12.5			APR-27-66	5042		SALIVARY GLAND ADENOCARCINOMA
F018R00	497	12.0			MAY-25-66	5321		HEMANGIOSARCOMA (SOFT TISSUE)
F019R00	533	8.42			OCT-13-66	4726		PNEUMONIA, MAMMARY ADENOCARCINOMA
M020R00	536	9.70			DEC-29-66	4890		SENILITY, INANITION
F021R00	549	9.90			JAN-26-67	4234		MAMMARY ADENOCARCINOMA
M022R00	533	12.1			MAR-22-67	3907		SEPTICEMIA
F031R00B	536	10.6			OCT-23-64	4458		STATUS EPILEPTICUS
F031R00C	536	9.88			OCT-23-64	4690		BILIARY OBSTRUCTION, LEIOMYOSARCOMA (VAGINA)
F031R00D	542	9.90			SEP-21-65	4889		PANCREATITIS
F032R00B	542	7.80			SEP-21-65	4657		VALVULAR INSUFFICIENCY, PANCREATITIS
F032R00C	532	11.7			SEP-21-65	4784		MAMMARY CARCINOMA
F032R00D	532	9.70			SEP-21-65	4828		TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
F033R00B	532	9.80			SEP-21-65	3670		MAMMARY ADENOCARCINOMA
F033R00C	496	9.50			MAY-25-66	4509		MELANOMA (MOUTH)
F033R00D	496	11.8			MAY-25-66	3916		MAMMARY ADENOCARCINOMA
F034R00B	525	8.20			JAN-26-67	4929		PANCREATITIS
F034R00C	520	8.90			MAR-22-67	4605		PANCREATITIS
F034R00D	484	9.90			MAR-22-67	3185		HEMANGIOSARCOMA (SOFT TISSUE)
F035R00B	502	9.41			FEB-01-68	5349		OVARIAN ADENOCARCINOMA
F035R00C	502	9.38			FEB-01-68	5066		SENILITY
F035R00D	552	8.86			JAN-09-69	5124		ENDOMETRITIS, SEPTICEMIA
F036R00B	467	10.1			JUL-02-68	5281		MAMMARY ADENOCARCINOMA
F036R00C	467	9.17			JUL-02-68	4538		MAMMARY ADENOCARCINOMA
F036R00D	467	9.08			JUL-02-68	4403		MELANOMA (MOUTH)
F037R00B	801	11.1			MAY-20-69	4093		LYMPHOSARCOMA
F037R00C	501	10.4			SEP-23-70	2788		PNEUMONIA, STATUS EPILEPTICUS
F037R00D	501	10.9			SEP-23-70	5621		MAMMARY ADENOCARCINOMA
F038R00B	501	11.5			SEP-23-70	3821		ENCEPHALITIS

B.7 ^{226}Ra, Chronic Toxicity Study (continued)

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
	INJECTION							
M101R00Y								REASSIGNED, SEE M515R40+
M102R00Y								REASSIGNED, SEE M516R40+
M103R00Y								REASSIGNED, SEE M517R40+
F104R00Y								REASSIGNED, SEE F518R40+
F105R00Y								REASSIGNED, SEE F519R40+
F106R00Y								REASSIGNED, SEE F520R40+
M107R00Y	94	4.32			MAR-09-77	5256		LYMPHOSARCOMA
F108R00Y	93	4.22			MAR-16-77	4301		SOLID CARCINOMA, MAMMARY GLAND
F109R00Y	88	2.92			JAN-19-78	5002		LIVING
M013R02	529	9.77	0.00577	0.213	MAR-04-64	4518	0.20	MELANOMA (MOUTH)
F014R02	460	8.10	0.00836	0.309	OCT-23-64	3448	0.42	MELANOMA (MOUTH)
M015R02	504	10.8	0.00873	0.323	FEB-04-65	4102	0.31	CIRCULATORY FAILURE
F016R02	486	8.90	0.00665	0.246	APR-07-65	4190	0.27	LYMPHOSARCOMA, MELANOMA (SKIN)
M017R02	494	11.8	0.00711	0.263	APR-27-66	5056	0.34	SENILITY, NEPHRITIS, LYMPHADENOPATHY
F018R02	497	9.30	0.00652	0.241	MAY-25-66	3387	0.24	LUNG CARCINOMA, ADENOCARCINOMA
F019R02	533	10.6	0.00785	0.290	OCT-13-66	3611	0.31	PNEUMONIA
M020R02	546	11.4	0.00676	0.250	DEC-29-66	3493	0.21	LYMPHOSARCOMA
F021R02	549	11.5	0.00687	0.254	JAN-26-67	3101	0.27	MAMMARY ADENOCARCINOMA
M022R02	533	12.9	0.00[illegible]	0.356	MAR-22-67	5000	0.40	PANCREATITIS
M013R05	529	11.0	0.0171	0.633	MAR-04-64	3676	0.58	CHOLANGIOCARCINOMA
F014R05	510	9.75	0.0220	0.814	OCT-23-64	5079	0.86	OSTEOSARCOMA
M015R05	490	10.4	0.0263	0.973	FEB-04-65	4297	0.83	MELANOMA (MOUTH)
F016R05	500	11.4	0.0205	0.759	APR-07-65	4141	0.81	MAMMARY ADENOCARCINOMA
M017R05	523	9.20	0.0215	0.796	APR-27-66	4052	0.73	MELANOMA (MOUTH)
F018R05	496	9.10	0.0197	0.729	MAY-25-66	4900	0.97	MELANOMA (MOUTH)
F019R05	533	10.0	0.0230	0.851	OCT-13-66	5059	1.06	MAMMARY CARCINOMA, DEGENERATION (KIDNEY)
M020R05	536	13.2	0.0206	0.762	DEC-29-66	4526	0.94	NEPHRITIS
F021R05	538	8.80	0.0208	0.770	JAN-26-67	4281	0.68	HEMORRHAGE (HYPOTHALAMUS), ULCER (STOMACH)
M022R05	520	12.3	0.0290	1.070	MAR-22-67	3192	1.01	THYROID ADENOCARCINOMA
M031R05B	508	11.4	0.0210	0.777	APR-27-66	4310	0.86	THYROID ADENOCARCINOMA,ANKYLOSING SPONDYLITIS
F031R50C	537	9.40	0.0235	0.870	DEC-22-65	4393	0.95	TRAUMA
F031R05D	537	11.7	0.0238	0.881	DEC-22-65	4797	0.92	THYROID ADENOCARCINOMA
M032R05B	496	13.4	0.0196	0.725	MAY-25-66	3219	0.75	THYMOMA
F032R05C	519	10.1	0.0239	0.884	DEC-22-65	4180	0.86	ADAMANTINOMA (MANDIBLE)
F032R05D	509	10.1	0.0240	0.888	DEC-22-65	3870	0.87	HEMANGIOSARCOMA (SOFT TISSUE)
M033R05B	497	12.9	0.0194	0.718	MAY-25-66	3848	0.85	EPIDERMOID CARCINOMA (MOUTH)
F033R05C	527	10.6	0.0212	0.784	APR-27-66	4935	0.96	INANITION UNDETERMINED (NO SKELETAL TUMOR)
F033R05D	527	8.70	0.0217	0.803	APR-27-66	4697	0.99	BILE DUCT OBSTRUCTION, KIDNEY FAILURE
M034R05B	496	10.5	0.0196	0.725	MAY-25-66	5249	0.96	ANKYLOSING SPONDYLITIS, MELANOMA (MOUTH)
F034R05C	524	9.90	0.0215	0.796	APR-27-66	4322	0.63	MAMMARY ADENOCARCINOMA
F034R05D	508	9.70	0.0212	0.784	APR-27-66	4628	0.92	TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
M035R05B	536	10.4	0.0205	0.759	DEC-29-66	4367	0.78	PROSTATITIS
F035R05C	532	9.00	0.0201	0.744	DEC-29-66	4990	0.74	SURGICAL COMPLICATIONS
F035R05D	532	10.2	0.0202	0.747	DEC-29-66	5171	0.81	THROMBOEMBOLISM, MAMMARY ADENOCARCINOMA

B.7 ^{226}Ra, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M101R05Y	88	4.32	0.0186	0.693	MAR-25-75	5217	0.95	MESOTHELIOMA/PAPILLARY ADENOCARCINOMA, LUNG
M102R05Y	93	4.44	0.0187	0.692	APR-24-75	4798	0.80	ADENOCARCINOMA (COLON)
M103R05Y	[illegible]	3.61	0.0192	0.710	MAY-06-75	5091	0.89	LYMPHOSARCOMA, SMALL INTESTINE
F104R05Y	88	4.09	0.0184	0.681	MAR-25-75	5249	1.02	PYELONEPHRITIS
F105R05Y	88	4.08	0.0184	0.681	MAR-25-75	4811	0.87	THROMBOSIS (LUNG), AMYLOIDOSIS KIDNEY
F106R05Y	93	3.50	0.0188	0.696	APR-24-75	4978	0.81	BETA CELL CARCINOMA, PANCREAS
M107R05Y	93	3.69	0.0191	0.707	MAR-08-77	4428	0.82	CARCINOMA, PROSTATE
M108R05Y	88	2.54	0.0185	0.685	JAN-19-78	5002		LIVING
F109R05Y	90	3.45	0.0177	0.655	MAR-09-78	4953		LIVING
F110R05Y	91	3.11	0.0195	0.722	AUG-08-78	3001	0.49	PULMONARY CALCIFICATION, MAMMARY ADENOCARCINOMA
M001R10	471	8.48	0.0618	2.29	APR-20-53	5727	1.73	MELANOMA (MOUTH)
M002R10	627	10.0	0.0876	3.24	NOV-16-53	4054	1.96	SEMINOMA
F003R10	706	8.68	0.0576	2.13	MAR-10-54	3360	0.85	MAMMARY ADENOCARCINOMA
M004R10	414	8.60	0.0642	2.38	APR-07-54	2038	1.10	TRAUMA
M005R10	490	11.7	0.0436	1.61	JUN-22-54	3780	1.25	TRANS. CELL CARC. (URINARY BLADDER),HYDRONEPHROSIS
F006R10	483	7.23	0.0584	2.16	JUL-27-54	5260	1.93	NEPHRITIS
M007R10	511	11.4	0.0651	2.41	AUG-24-54	3544	1.71	STATUS EPILEPTICUS
F008R10	861	8.98	0.0559	2.07	DEC-21-54	2988	0.97	LYMPHOSARCOMA
F009R10	781	9.88	0.0521	1.93	APR-11-55	4399	1.04	PNEUMONIA
M010R10	523	11.5	0.0573	2.12	JUL-27-55	4003	1.65	FIBROSARCOMA GINGIVA, MELANOMA (EYE)
F011R10	511	11.2	0.0522	1.93	DEC-20-55	5636	1.61	MELANOMA (EYE), MAMMARY ADENOCARCINOMA
F012R10	501	9.71	0.0444	1.64	JAN 17-56	3978	1.29	MELANOMA (MOUTH)
M013R10	529	11.7	0.0527	1.95	MAR-04-64	3739	1.82	CYST (PROSTATE), ADENOCARCINOMA (PROSTATE)
F014R10	510	10.5	0.0701	2.59	OCT-23-64	1729	1.63	STATUS EPILEPTICUS
M015R10	490	8.83	0.0797	2.95	FEB-04-65	893	0.92	SUBDURAL HEMORRHAGE (SPINAL CORD)
F016R10	501	8.99	0.0611	2.26	APR-07-65	4557	1.93	LYMPHOSARCOMA
M017R10	494	11.4	0.0639	2.36	APR-27-66	5601	2.63	NEPHRITIS
F018R10	496	10.0	0.0589	2.18	MAY-25-66	3625	1.67	MAMMARY ADENOCARCINOMA
F019R10	533	11.6	0.0682	2.52	OCT-13-66	3612	2.33	OSTEOSARCOMA
M020R10	536	10.0	0.0610	2.26	DEC-29-66	4260	2.71	CHONDROSARCOMA (ETHMOID), ADENOCARCINOMA (ADRENAL)
F021R10	525	8.10	0.0633	2.34	JAN-26-67	5189	2.07	PNEUMONIA
M022R10	484	10.9	0.0861	3.19	MAR-22-67	4845	4.59	PROSTATE ADENOCARC.,TRANS. CELL CARC. (BLADDER)
F031R10B	509	10.4	0.0712	2.63	DEC-22-65	3009	1.77	STATUS EPILEPTICUS
M101R10Y	88	4.07	0.0545	2.02	MAR-25-75	5787	2.59	ADENOMA,PITUITARY
M102R10Y	92	4.54	0.0546	2.02	APR-01-75	4384	2.22	MAST CELL SARCOMA (INTESTINE)
M103R10Y	90	3.03	0.0564	2.09	MAY-06-75	4264	2.09	CHRONIC PANCREATITIS
F104R10Y	88	3.71	0.0541	2.00	MAR-25-75	5161	2.26	CHONDROSARCOMA, NASAL CAVITY
F105R10Y	92	4.70	0.0523	1.95	APR-01-75	4182	1.90	CHRONIC PANCREATITIS
F106R10Y	93	4.20	0.0557	2.06	APR-24-75	4144	2.17	HEMORRHAGE (SPLEEN)
M107R10Y	93	4.12	0.0575	2.13	MAR-08-77	2010	1.23	INFECTION
M108R10Y	88	2.52	0.0548	2.03	JAN-19-78	2467	1.27	THROMBOLISM
F109R10Y	90	3.61	0.0544	2.01	MAR-09-78	3907	1.84	HEPATOCELLULAR CARCINOMA
M111R10Y	90	2.95	0.0527	1.95	MAY-23-78	4283	2.25	ADENOCARCINOMA, NASAL MUCOSA
M001R17	523	9.98	0.137	5.07	JAN-17-56	4438	3.61	THROMBOEMBOLISM, MELANOMA EYE

B.7 ^{226}Ra, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M002R17	598	7.85	0.163	6.03	NOV-30-56	1273	1.27	LYMPHOSARCOMA
M002R17A	493	12.0	0.222	8.21	MAR-06-63	3254	7.22	FIBROSARCOMA (GUM OF MAXILLA)
F003R17	473	13.1	0.165	6.11	DEC-20-55	3268	4.42	MAMMARY ADENOCARCINOMA
M004R17	514	6.20	0.163	6.03	DEC-20-55	5495	5.39	NEPHRITIS
M005R17	511	10.1	0.151	5.59	DEC-20-55	4107	5.08	OSTEOSARCOMA
F006R17	491	7.90	0.152	5.62	DEC-20-55	3432	4.89	GENERALIZED CALCINOSIS
M007R17	598	7.17	0.163	6.03	NOV-30-56	3142	3.30	TOXEMIA (BACTERIAL), THYROID ADENOCARCINOMA
F008R17	491	9.50	0.154	5.70	DEC-20-55	2577	3.92	DRUG ALLERGY
F009R17	598	7.55	0.168	6.22	NOV-30-56	3914	2.87	ENDOMETRITIS
M010R17	590	9.57	0.167	6.18	NOV-30-56	557	1.14	TRAUMA
M010R17A	545	10.6	0.183	6.77	JAN-07-59	4903	5.57	UNDIFFERENTIATED MALIGNANCY,(NO SKELETAL TUMOR)
F011R17	598	8.17	0.165	6.11	NOV-30-56	5324	3.34	MELANOMA (MOUTH), THYROID ADENOCARCINOMA
F012R17	590	8.95	0.167	6.18	NOV-30-56	2399	2.28	ENCEPHALOPATHY
M101R17Y	92	4.19	0.163	6.03	APR-01-75	4587	6.83	MALABSORPTION SYNDROME
M102R17Y	93	5.45	0.167	6.18	APR-24-75	3844	5.28	SARCOMA (MYOCARDIUM)
M103R17Y	90	2.84	0.167	6.18	MAY-06-75	3450	5.80	INANITION
F104R17Y	88	3.65	0.159	5.88	MAR-25-75	2369	3.97	STATUS EPILEPTICUS
F105R17Y	88	3.66	0.158	5.85	MAR-25-75	4315	5.95	THROMBOEMBOLISM
F106R17Y	93	3.62	0.180	6.66	APR-24-75	4009	6.44	MAMMARY ADENOCARCINOMA
M107R17Y	93	3.77	0.166	6.14	MAR-16-77	8	0.02	ANESTHESIA ACCIDENT
M108R17Y	88	3.95	0.180	6.66	APR-20-78	4911		LIVING
F109R17Y	90	2.98	0.164	6.07	MAY-23-78	4878		LIVING
F110R17Y	91	2.24	0.160	5.92	JUN-20-78	4733	6.81	MALIGNANT EPULIS
M111R17Y	90	3.39	0.158	5.85	MAY-23-78	4878		LIVING
M001R20	471	8.74	0.382	14.1	APR-20-53	3440	8.71	HEMANGIOSARCOMA (SOFT TISSUE)
M002R20	592	8.21	0.387	14.3	NOV-16-53	3775	6.45	OSTEOSARCOMA, MELANOMA (EYE)
F003R20	541	8.53	0.347	12.8	MAR-10-54	4459	8.97	LYMPHOSARCOMA
M004R20	414	10.5	0.361	13.4	APR-07-54	325	1.90	PERFORATION (ILEUS)
M004R20A	420	10.6	0.306	11.3	APR-11-55	4368	11.8	VALVULAR ENDOCARDITIS, MELANOMA (EYE)
M005R20	461	11.5	0.267	9.88	JUN-22-54	4703	10.2	OSTEOSARCOMA, ADRENAL CORTEX ADENOCARCINOMA
F006R20	466	10.6	0.360	13.3	JUL-27-54	4615	13.0	EPIDERMOID CARCINOMA (TYMPANIC BULLA)
M007R20	514	11.1	0.413	15.3	AUG-24-54	3424	9.52	OSTEOSARCOMA, CUSHING'S DISEASE
F008R20	572	6.95	0.331	12.2	DEC-21-54	4781	10.3	UNDIFFERENTIATED MALIGNANCY (INTESTINE)
F009R20	592	9.38	0.317	11.7	APR-11-55	3998	7.12	MAMMARY ADENOCARCINOMA
M010R20	523	9.95	0.345	12.8	JUL-27-55	3569	12.6	OSTEOSARCOMA
F011R20	495	9.30	0.310	11.5	DEC-20-55	3297	8.56	OSTEOSARCOMA
F012R20	497	10.3	0.281	10.4	JAN-17-56	2948	7.70	MAMMARY ADENOCARCINOMA
M101R20Y	90	4.64	0.317	11.7	MAR-07-75	3022	9.51	OSTEOSARCOMA
M102R20Y	90	4.27	0.324	12.0	MAR-07-75	3492	10.6	OSTEOSARCOMA
M103R20Y	90	5.35	0.320	11.8	MAR-07-75	4135	13.5	PROSTATIC CARCINOMA
F104R20Y	90	4.36	0.317	11.7	MAR-07-75	3980	12.0	OSTEOSARCOMA, MAMMARY ADENOCARCINOMA
F105R20Y	90	3.93	0.321	11.9	MAR-07-75	3023	8.73	THROMBOEMBOLISM, INFARCTION
F106R20Y	89	4.19	0.309	11.4	MAR-14-75	3664	10.2	ENDOMETRITIS, NEPHRITIS, PNEUMONIA
M107R20Y	93	4.53	0.329	12.2	MAR-16-77	5311		LIVING

B.7 ^{226}Ra, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M108R20Y	88	4.43	0.348	12.9	APR-20-78	3142	9.80	OSTEOSARCOMA
F109R20Y	88	2.79	0.332	12.3	JAN-19-78	5002		LIVING
F110R20Y	90	3.55	0.320	11.8	JUN-20-78	4245	10.05	COMBINED OSTEOSARCOMA, ISCHIUM
M001R30	473	8.91	1.20	44.4	APR-20-53	2850	24.2	OSTEOSARCOMA
M002R30	470	9.02	1.21	44.8	NOV-16-53	2226	17.6	OSTEOSARCOMA
F003R30	386	7.74	1.11	41.1	MAR-10-54	2497	23.7	OSTEOSARCOMA
M004R30	412	11.7	1.16	42.9	APR-07-54	1917	24.0	OSTEOSARCOMA
M005R30	461	13.0	0.846	31.3	JUN-22-54	2955	23.7	OSTEOSARCOMA
F006R30	486	9.75	1.14	42.2	JUL-27-54	1932	22.9	OSTEOSARCOMA
M007R30	514	12.3	1.29	47.7	AUG-24-54	2099	30.9	OSTEOSARCOMA
F008R30	542	7.76	1.03	38.1	DEC-21-54	2612	19.8	OSTEOSARCOMA
F009R30	551	8.02	0.987	36.5	APR-11-55	2487	19.1	OSTEOSARCOMA
M010R30	525	10.1	1.06	39.2	JUL-27-55	1737	23.9	OSTEOSARCOMA
F011R30	495	12.9	0.938	34.7	DEC-20-55	1610	15.9	ENDOMETRITIS, PERITONITIS
F012R30	497	11.4	0.883	32.7	JAN-17-56	1897	17.0	OSTEOSARCOMA
M101R30Y	93	4.41	1.01	37.4	APR-24-75	2965	32.9	EPIDERMOID CARCINOMA (MIDDLE EAR)
M102R30Y	93	5.40	1.01	37.4	APR-24-75	2231	24.3	OSTEOSARCOMA
M103R30Y	90	2.94	1.08	40.0	MAY-06-75	2513	25.9	PATHOLOGICAL FRACTURE
F104R30Y	88	3.74	1.02	37.7	MAR-25-75	2728	27.4	THROMBOEMBOLISM
F105R30Y	93	4.51	1.02	37.7	APR-24-75	2504	25.0	OSTEOSARCOMA
F106R30Y	90	3.25	1.07	39.6	MAY-06-75	2102	26.0	OSTEOSARCOMA
M107R30Y	88	2.46	1.05	38.8	JAN-19-78	2602	27.1	OSTEOSARCOMA
M108R30Y	88	2.34	1.05	38.8	MAY-09-78	3788	32.5	OSTEOSARCOMA, METATARSUS
F109R30Y	93	3.40	1.09	40.3	JAN-19-78	2862	23.3	OSTEOSARCOMA
F110R30Y	94	3.04	1.02	37.7	AUG-08-78	1659	16.7	OSTEOSARCOMA
F501R30+	1787	10.4	0.806	29.8	JUN-10-75	1799	20.8	OSTEOSARCOMA
F502R30+	1918	8.26	0.972	36.0	SEP-22-76	2772	13.4	OSTEOSARCOMA
F503R30+	1836	10.0	1.08	40.0	NOV-29-77	2249	12.2	LYMPHOSARCOMA
F504R30+	1876	9.33	1.02	37.7	OCT-05-78	3322	15.6	THROMBOSIS (LUNG), AMYLOIDOSIS KIDNEY
F505R30+	1815	8.15	1.23	45.5	NOV-02-78	1776	14.1	OSTEOSARCOMA
M506R30+	1868	9.72	1.00	37.0	OCT-05-78	21	0.32	ANESTHESIA ACCIDENT
M507R30+	1881	10.8	1.01	37.4	OCT-05-78	2591	14.7	THROMBOEMBOLISM, OSTEOPOROSIS
M508R30+	1876	11.5	1.01	37.4	OCT-05-78	2086	15.7	PROSTATITIS, NEPHRITIS
M509R30+	1829	11.8	1.23	45.5	NOV-02-78	2035	17.0	FIBROSARCOMA (SKELETON)
M510R30+	1817	10.6	1.23	45.5	NOV-02-78	1671	11.6	OSTEOSARCOMA
M001R40	471	9.03	3.51	130.	APR-20-53	1606	66.1	OSTEOSARCOMA
M002R40	470	9.53	3.55	131.	NOV-16-53	1884	62.4	OSTEOSARCOMA
F003R40	384	8.65	3.33	123.	MAR-10-54	490	22.3	CANINE DISTEMPER
F003R40A	398	7.20	3.10	115.	NOV-30-56	1614	41.0	OSTEOSARCOMA
M004R40	408	8.83	3.47	128.	APR-07-54	1518	61.5	OSTEOSARCOMA
M005R40	461	13.2	2.42	89.5	JUN-22-54	1659	45.8	OSTEOSARCOMA
F006R40	486	8.55	3.44	127.	JUL-27-54	1939	72.7	OSTEOSARCOMA
M007R40	453	9.55	3.88	144.	AUG-24-54	1647	59.9	OSTEOSARCOMA
F008R40	474	8.94	3.14	116.	DEC-21-54	1324	47.2	OSTEOSARCOMA

B.7 ^{226}Ra, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F009R40	542	8.53	3.02	112.	APR-11-55	1471	42.3	OSTEOSARCOMA
M010R40	527	10.8	3.28	121.	JUL-27-55	1553	77.4	OSTEOSARCOMA
F011R40	491	10.4	2.84	105.	DEC-20-55	1469	54.3	OSTEOSARCOMA
F012R40	496	9.61	2.81	104.	JAN-17-56	1435	40.4	OSTEOSARCOMA
F501R40+	1787	10.5	2.50	92.5	JUN-10-75	303	20.8	PERITONITIS
F502R40+	1933	9.09	2.96	110.	SEP-22-76	1674	55.9	OSTEOSARCOMA, HEMOTHORAX
F503R40+	1536	10.9	3.44	127.	NOV-29-77	1521	47.2	OSTEOSARCOMA
F504R40+	1835	7.93	1.98	73.3	JAN-10-78	636	9.80	NEPHRITIS, STATUS EPILEPTICUS
F505R40+	1876	11.6	2.89	107.	OCT-05-78	1380	37.2	CRIPPLING FRACTURE
M506R40+	1881	10.[illegible]	2.97	110.	OCT-05-78	1692	41.0	OSTEOSARCOMA, NEPHRITIS
M507R40+	1823	11.7	3.04	112.	MAY-09-78	1462	39.0	NEPHRITIS
M508R40+	1845	10.5	2.99	111.	OCT-05-78	1365	40.4	OSTEOSARCOMA
M509R40+	1817	13.2	3.65	135.	NOV-02-78	952	31.4	LEIOMYOSARCOMA
M510R40+	1807	12.2	3.61	134.	NOV-02-78	516	20.5	NEPHRITIS, CRIPPLING FRACTURE
F511R40+	2254	10.7	3.88	144.	AUG-19-80	1318	43.0	OSTEOSARCOMA, NEPHRITIS
M512R40+	2187	13.7	3.03	112.	AUG-19-80	1680	43.1	OSTEOSARCOMA, NEPHROSIS
F513R40+	2239	10.9	3.20	118.	AUG-19-80	1675	34.1	OSTEOSARCOMA, NEPHROSIS
F514R40+	2022	11.4	3.20	118.	AUG-19-80	1182	33.9	OSTEOSARCOMA
M515R40+	2087	10.0	3.21	119.	SEP-16-80	702	22.8	MAST CELL SARCOMA
M516R40+	2090	13.2	3.21	119.	SEP-16-80	1803	41.1	OSTEOSARCOMA, CHOLANGIOCARCINOMA
M517R40+	2065	12.6	3.17	117.	SEP-16-80	674	19.6	NEPHRITIS
F518R40+	2102	9.87	3.18	118.	SEP-16-80	678	18.2	NEPHRITIS, PNEUMONIA
F519R40+	2090	10.5	3.21	119.	SEP-16-80	1662	36.3	OSTEOSARCOMA
F520R40+	2087	9.43	3.25	120.	SEP-16-80	1323	41.4	OSTEOSARCOMA, NEPHROSIS
M001R50	473	6.87	10.5	389.	APR-20-53	908	150.	OSTEOSARCOMA
M002R50	470	8.85	10.8	400.	NOV-16-53	1380	183.	OSTEOSARCOMA
F003R50	380	7.82	10.1	374.	MAR-10-54	481	72.4	CANINE DISTEMPER
M004R50	408	8.90	10.6	392.	APR-07-54	1091	167.	OSTEOSARCOMA
M005R50	458	10.9	10.1	374.	JUN-22-54	1220	157.	OSTEOSARCOMA
F006R50	486	9.66	10.2	377.	JUL-27-54	1015	157.	OSTEOSARCOMA
M007R50	453	8.85	11.9	440.	AUG-24-54	1288	171.	OSTEOSARCOMA
F008R50	474	7.76	9.68	358.	DEC-21-54	968	119.	OSTEOSARCOMA
F009R50	420	9.16	9.48	351.	APR-11-55	1788	164.	OSTEOSARCOMA, ANEMIA
M010R50	527	10.7	10.2	377.	JUL-27-55	825	115.	OSTEOSARCOMA, CRIPPLING FRACTURE
F501R50+	1827	12.8	10.2	377.	AUG-16-77	266	31.5	NEPHRITIS
F502R50+	1812	9.65	9.97	369.	NOV-29-77	1219	166.	OSTEOSARCOMA
F503R50+	1819	10.8	6.31	233.	JAN-10-78	419	32.5	NEPHRITIS
F504R50+	1855	7.52	9.22	341.	MAY-09-78	420	32.3	NEPHRITIS

F042R008 WAS REMOVED FROM INJECTION TABLES BECAUSE DOG NEVER REACHED YOUNG ADULT AGE.

B.8 ^{228}Ra (Mesothorium), Chronic Toxicity Study

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F001M00	732	7.33			JAN-04-54	3451		MENINGOENCEPHALITIS
F002M00	545	6.94			NOV-29-54	6155		SENILITY
M003M00	579	13.0			MAR-13-56	5056		INFARCTION (BRAIN)
M004M00	601	10.3			JAN-15-57	4816		VALVULAR ENDOCARDITIS MYOCARDIAL INFARCTION
F005M00	670	11.2			MAR-05-57	4591		MAMMARY ADENOCARCINOMA
M006M00	492	7.56			APR-23-57	4934		NEPHRITIS
F007M00	395	8.71			JUN-04-57	1414		STATUS EPILEPTICUS
F007M00A	594	10.9			JAN-15-63	3624		PNEUMONIA
F008M00	654	11.6			MAR-09-60	5009		THROMBOEMBOLISM
M009M00	575	12.4			APR-13-60	4132		PNEUMONIA
M010M00	581	13.3			JUL-17-62	2991		MELANOMA (MOUTH)
F011M00	475	9.31			SEP-18-62	3248		PNEUMONIA
M012M00	695	10.0			DEC-22-60	4810		THROMBOEMBOLISM,TRANS. CELL CARC. (URINARY BLADDER)
F001M05	492	9.47	0.0173	0.640	JUL-17-62	5460	0.70	THROMBOEMBOLISM, MELANOMA (EYE)
F002M05	492	9.15	0.0173	0.640	JUL-17-62	3689	0.94	PANCREATITIS
M003M05	493	10.8	0.0199	0.736	SEP-18-62	4697	1.13	THROMBOEMBOLISM, MELANOMA (EYE)
M004M05	475	12.8	0.0199	0.736	SEP-18-62	4193	1.20	LYMPHOSARCOMA
F005M05	534	7.83	0.0172	0.636	OCT-23-62	3958	0.81	LYMPHOSARCOMA
M006M05	510	10.3	0.0171	0.633	OCT-23-62	3019	0.71	MELANOMA (EYE)
F007M05	492	8.87	0.0172	0.636	JUL-17-62	4997	1.12	PNEUMONIA, MELANOMA (EYE)
F008M05	654	12.6	0.0159	0.588	MAR-09-60	4205	0.70	ENTERITIS, MELANOMA (EYE)
M009M05	485	11.9	0.0170	0.629	APR-13-60	5321	1.06	THROMBOEMBOLISM
M010M05	492	10.6	0.0174	0.644	JUL-17-62	4567	1.11	DEGENERATION (KIDNEY),THROMBOEMBOLISM, MELANOMA (EYE)
F011M05	505	7.82	0.0202	0.747	SEP-18-62	4033	1.06	BILIARY OBSTRUCTION, MELANOMA (EYE)
M012M05	510	10.6	0.0165	0.611	OCT-23-62	3920	0.84	STATUS EPILEPTICUS
F001M10	718	7.75	0.0463	1.71	JAN-04-54	2952	1.88	FIBROSARCOMA (SPLEEN)
F001M10A	590	8.07	0.0512	1.89	OCT-23-62	4292	2.19	NEPHRITIS,MELANOMA (EYE),PANCREATITIS,CHOLANGIOCARC.
F002M10	459	8.25	0.0324	1.20	NOV-29-54	5267	2.13	FIBROSARCOMA, GINGIVAL (R.MAXILLA), MELANOMA (EYE)
M003M10	575	13.8	0.0589	2.18	MAR-13-56	3157	3.06	OSTEOSARCOMA
M004M10	601	9.90	0.0481	1.78	JAN-15-57	4260	1.31	PNEUMONIA, PANCREATITIS, MELANOMA (EYE)
F005M10	658	8.80	0.0490	1.81	MAR-05-57	4565	1.92	MELANOMA (EYE)
M006M10	492	10.6	0.0463	1.73	APR-23-57	3402	2.73	EPIDERMOID CARCINOMA (PENIS)
F007M10	534	9.89	0.0489	1.81	JUN-04-57	2159	1.50	HEMANGIOSARCOMA
F008M10	654	12.4	0.0491	1.82	MAR-09-60	3886	2.41	MELANOMA (EYE)
M009M10	485	10.1	0.0504	1.86	APR-13-60	4670	3.12	VALVULAR ENDOCARDITIS
M010M10	492	9.43	0.0501	1.85	JUL-17-62	2566	2.13	MELANOMA (EYE)
F011M10	505	8.91	0.0613	2.27	SEP-18-62	4943	4.05	MAMMARY ADENOCARCINOMA
M012M10	528	9.27	0.0498	1.84	OCT-23-62	3786	2.32	LYMPHOSARCOMA
F001M17	510	7.52	0.151	5.59	OCT-23-62	4265	7.21	OSTEOSARCOMA
F002M17	560	9.90	0.183	6.77	MAR-13-56	2383	7.32	OSTEOSARCOMA
M003M17	576	11.0	0.180	6.66	MAR-13-56	2709	7.21	OSTEOSARCOMA
M004M17	601	8.94	0.143	5.29	JAN-15-57	2864	4.26	LYMPHOSARCOMA
F005M17	658	12.8	0.141	5.22	MAR-05-57	3234	6.29	OSTEOSARCOMA
M006M17	492	10.0	0.144	5.33	APR-23-57	3424	3.96	OSTEOSARCOMA

B.8 ^{228}Ra (Mesothorium), Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION: AGE (DAYS)	WEIGHT (KG)	INJECTED (UCi/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F007M17	534	10.2	0.146	5.40	JUN-04-57	2646	6.04	OSTEOSARCOMA, MELANOMA (EYE)
F008M17	654	10.8	0.148	5.48	MAR-09-60	2486	3.88	OSTEOSARCOMA
M009M17	485	12.6	0.149	5.51	APR-13-60	2799	6.86	OSTEOSARCOMA
M010M17	492	10.1	0.124	4.59	JUL-17-62	3101	7.53	OSTEOSARCOMA
F011M17	505	10.7	0.179	6.62	SEP-18-62	3325	10.1	OSTEOSARCOMA
M012M17	524	9.28	0.153	5.66	OCT-23-62	3017	7.23	UNDETERMINED (NO SKELETAL TUMOR)
F001M20	676	7.60	0.276	10.2	JAN-04-54	1760	8.28	OSTEOSARCOMA, MELANOMA (EYE)
F002M20	517	8.25	0.194	7.18	NOV-29-54	965	1.94	HEMORRHAGE (INTESTINE)
M003M20	576	11.0	0.358	13.2	MAR-13-56	619	3.27	PNEUMONIA
M004M20	601	9.83	0.282	10.4	JAN-15-57	2282	10.4	OSTEOSARCOMA
F005M20	508	8.30	0.295	10.9	MAR-05-57	2688	9.32	OSTEOSARCOMA
M006M20	501	12.4	0.306	11.3	APR-23-57	2674	13.9	OSTEOSARCOMA
F007M20	534	10.1	0.298	11.0	JUN-04-57	2239	10.7	PANCREATITIS
F008M20	654	12.4	0.300	11.1	MAR-09-60	2386	9.32	OSTEOSARCOMA
M009M20	630	9.99	0.302	11.2	APR-13-60	1254	5.63	OSTEOSARCOMA
M010M20	430	11.2	0.311	11.5	JUL-17-62	2373	14.6	OSTEOSARCOMA
F011M20	505	7.03	0.381	14.1	SEP-18-62	2878	11.0	OSTEOSARCOMA
M012M20	524	9.47	0.306	11.3	OCT-23-62	2471	13.3	OSTEOSARCOMA
F001M30	519	10.4	0.858	31.7	JAN-04-54	915	17.3	OSTEOSARCOMA
F002M30	460	6.70	0.612	22.6	NOV-29-54	1856	20.7	OSTEOSARCOMA
M003M30	579	10.4	0.965	35.7	MAR-13-56	1185	24.5	OSTEOSARCOMA
M004M30	601	10.2	0.916	33.9	JAN-15-57	1176	15.9	OSTEOSARCOMA
F005M30	531	8.51	0.940	34.8	MAR-05-57	1869	21.6	OSTEOSARCOMA
M006M30	501	9.09	0.953	35.3	APR-23-57	1421	19.1	OSTEOSARCOMA
F007M30	534	9.94	0.907	33.6	JUN-04-57	1463	31.6	OSTEOSARCOMA
F008M30	633	11.8	0.950	35.1	MAR-09-60	1447	21.7	OSTEOSARCOMA
M009M30	630	9.83	0.918	34.0	APR-13-60	1570	22.9	OSTEOSARCOMA
M010M30	581	10.4	1.00	37.0	JUL-17-62	1575	23.3	OSTEOSARCOMA
F011M30	499	11.0	1.19	44.0	SEP-18-62	1395	24.7	OSTEOSARCOMA
M012M30	510	12.9	0.987	36.5	OCT-23-62	1638	23.8	OSTEOSARCOMA
F001M40	509	7.56	2.60	96.2	JAN-04-54	841	53.9	OSTEOSARCOMA, CRIPPLING FRACTURE
F002M40	460	6.95	1.86	68.8	NOV-29-54	778	22.3	OSTEOSARCOMA
M003M40	579	9.65	3.37	125.	MAR-13-56	418	17.3	STRANGULATED HERNIA
M003M40A	494	7.34	2.64	97.7	JUN-04-57	1063	56.2	OSTEOSARCOMA, NEPHRITIS, ULCER (MOUTH)
M004M40	609	7.84	2.47	91.4	JAN-15-57	896	26.8	CRIPPLING FRACTURE, ULCER (MOUTH)
F005M40	508	9.63	2.67	98.8	MAR-05-57	1064	43.6	OSTEOSARCOMA
M006M40	501	9.49	2.66	98.4	APR-23-57	1121	47.9	OSTEOSARCOMA
F007M40	543	8.40	2.67	98.8	JUN-04-57	1253	46.5	OSTEOSARCOMA
F001M50	493	7.77	8.11	300.	JAN-04-54	232	34.3	NEPHRITIS, ANEMIA
F002M50	460	7.35	5.46	202.	NOV-29-54	780	75.5	CRIPPLING FRACTURE
M003M50	579	8.87	10.4	385.	MAR-13-56	688	140.	ULCER (MOUTH)
M004M50	482	7.29	7.89	292.	JAN-15-57	561	56.3	CRIPPLING FRACTURE
F005M50	658	11.1	8.48	314.	MAR-05-57	770	95.4	ULCER (MOUTH)

B.8 ^{228}Ra (Mesothorium), Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M006M50	580	7.53	8.67	321.	APR-23-57	792	67.3	OSTEOSARCOMA, CRIPPLING FRACTURE
F007M50	494	7.35	8.92	330.	JUN-04-57	966	181.	ULCER (MOUTH), MYOCARDIAL INFARCTION

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(KBQ TH-228/KBQ RA-228) INJECTED = 0.15 FOR F001M10, F001M20, F001M30, F001M40, F001M50.

= 0.03 FOR F002M10, F002M17, F002M20, F002M30, F002M40, F002M50
M003M10, M003M17, M003M20, M003M30, M003M40, M003M50.

= 0.006 FOR GROUPS 4, 5, 6, 7, 8, 9, 10, 11, 12, AND FOR DOGS
F001M05, F002M05, M003M05, F001M10A, F001M17, M003M40A.

B.9 ^{90}Sr, Chronic Toxicity Study

DOG NUMBER	INJECTION: AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
F001S00	502	8.48			JAN-18-55	5484		PANCREAS ADENOCARCINOMA
M002S00	600	11.1			FEB-14-56	3838		LUNG CARCINOMA
M003S00	493	9.03			SEP-11-57	3516		OBTURATING AORTIC EMBOLISM, NEPHRITIS
F004S00	520	8.19			OCT-15-57	5755		NEPHRITIS, SENILITY
M005S00	542	10.6			NOV-19-57	4158		TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
M006S00	466	9.68			MAY-27-58	4726		MELANOMA (MOUTH)
F007S00A	462	9.46			JAN-07-59	3303		DIABETES MELLITUS
F008S00	483	9.29			MAY-19-59	4482		DIABETES MELLITUS
F009S00	549	12.4			AUG-11-59	708		TRAUMA
F009S00A	535	11.2			JUN-04-63	3425		MAMMARY ADENOCARCINOMA
M010S00	522	13.9			SEP-29-59	4977		FIBROMA (SOFT TISSUE)
F011S00	541	9.60			NOV-03-59	4831		MAMMARY ADENOCARCINOMA
M012S00	605	8.99			JAN-06-60	5374		CARCINOMA (INTESTINE), SENILITY
F001S10	1524	6.84	0.573	21.2	JAN-18-55	308	0.20	IMPROPER INJECTION AGE
F001S10A	521	9.38	0.588	21.8	FEB-14-56	5219	0.90	THROMBOEMBOLISM
M002S10	567	8.81	0.606	22.4	FEB-14-56	5077	0.90	AORTIC BODY TUMOR
M003S10	493	10.9	0.572	21.2	SEP-11-57	5363	1.42	EPIDERMOID CARCINOMA (MOUTH)
F004S10	525	8.96	0.560	20.7	OCT-15-57	5902	1.48	NEPHRITIS, MAMMARY ADENOCARCINOMA
M005S10	555	10.2	0.532	19.7	NOV-19-57	2705	0.70	STATUS EPILEPTICUS
M006S10	466	9.56	0.581	21.5	MAY-27-58	5739	2.20	LYMPHOSARCOMA
F007S10	524	9.94	0.517	19.1	NOV-11-58	5837	1.21	LYMPHOSARCOMA, MAMMARY ADENOCARCINOMA
F008S10	483	10.8	0.697	25.8	MAY-19-59	2784	0.78	ISLET CELL, ADENOCARCINOMA
F009S10	549	11.6	0.534	19.8	AUG-11-59	3601	0.87	PNEUMONIA, ENTERITIS
M010S10	522	11.5	0.558	20.6	SEP-29-59	5321	1.20	SEBACEOUS GLAND ADENOCARCINOMA
F011S10	543	10.3	0.550	20.4	NOV-03-59	4944	1.06	TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
M012S10	607	13.7	0.559	20.7	JAN-06-60	4184	0.95	BILIARY OBSTRUCTION
F001S17	526	7.41	1.78	65.9	FEB-14-56	5624	4.72	HEMANGIOENDOTHELIAL SARCOMA (LIVER)
M002S17	567	11.6	1.84	68.1	FEB-14-56	4297	4.07	HEMORRHAGE (SOFT TISSUE)
M003S17	493	9.19	1.69	62.5	SEP-11-57	4846	3.37	THROMBOEMBOLISM
F004S17	522	9.60	1.68	62.2	OCT-15-57	4629	2.96	PANCREAS ADENOCARCINOMA
M005S17	560	9.85	1.60	59.2	NOV-19-57	1715	1.64	COMA (NO SKELETAL TUMOR)
M005S17A	493	11.4	1.78	65.9	MAR-06-63	5379	5.73	SENILITY
M006S17	466	10.6	1.72	63.6	MAY-27-58	5581	5.43	TRANSITIONAL CELL CARC. (URINARY BLADDER),NEPHROSIS
F007S17	488	10.2	1.60	59.2	NOV-11-58	3990	2.47	ARTHRITIS, MAMMARY ADENOCARCINOMA
F008S17	472	8.47	2.03	75.1	MAY-19-59	1973	2.13	STATUS EPILEPTICUS, PANCREATITIS
F009S17	549	10.0	1.62	59.9	AUG-11-59	4803	4.13	LYMPHOSARCOMA, NEPHRITIS
M010S17	519	13.6	1.66	61.4	SEP-29-59	2947	3.04	THROMBOEMBOLISM, NEPHRITIS LUNG
F011S17	543	11.0	1.68	62.2	NOV-03-59	3180	2.38	THROMBOEMBOLISM, CALCIFICATION (LUNG)
M012S17	607	11.9	1.68	62.2	JAN-06-60	4717	3.55	ISLET CELL TUMOR
F001S20	502	5.59	3.70	137.	JAN-18-55	3269	4.75	PNEUMONIA
M002S20	567	8.97	3.42	127.	FEB-14-56	3768	6.29	LYMPHOSARCOMA, LUNG CARCINOMA
M003S20	493	7.82	3.39	125.	SEP-11-57	4295	6.68	STATUS EPILEPTICUS, THYROID CARCINOMA
F004S20	522	9.68	3.41	126.	OCT-15-57	4775	7.35	MAMMARY ADENOCARCINOMA
M005S20	560	8.72	3.24	120.	NOV-19-57	3253	5.28	ULCER (STOMACH)

B.9 ^{90}Sr, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M006S20	466	9.19	3.50	130.	MAY-27-58	5193	8.47	UNDIFFERENTIATED SARCOMA (LIVER), NEPHRITIS
F007S20	488	11.2	3.19	118.	NOV-11-58	3421	4.55	ISLET CELL ADENOMA
F008S20	465	9.49	4.14	153.	MAY-19-59	3955	6.83	PNEUMONIA
F009S20	473	14.1	3.28	121.	AUG-11-59	2467	5.62	UNDETERMINED (NO SKELETAL TUMOR)
M010S20	508	10.7	3.34	124.	SEP-29-59	3436	5.91	VALVULAR ENDOCARDITIS
F011S20	543	10.4	3.41	126.	NOV-03-59	4880	6.58	MAMMARY SARCOMA
M012S20	607	11.6	3.49	129.	JAN-06-60	4584	7.06	HEPATIC CELL CARCINOMA
F001S30	468	7.36	11.6	429.	JAN-18-55	5149	32.9	UNDETERMINED (NO SKELETAL TUMOR)
M002S30	564	9.62	11.6	429.	FEB-14-56	4263	26.0	NEPHRITIS
M003S30	494	11.4	10.8	400.	SEP-11-57	4947	24.0	SEMINOMA, HYDROCEPHALUS
F004S30	527	9.17	10.6	392.	OCT-15-57	3101	14.8	MAMMARY ADENOCARCINOMA
M005S30	557	8.90	10.1	374.	NOV-19-57	4640	21.3	SERTOLI CELL TUMOR
M006S30	466	9.44	10.9	403.	MAY-27-58	5667	30.8	NEPHRITIS, MALIGNANCY (TESTES)
F007S30	486	9.80	10.1	374.	NOV-11-58	4018	18.1	OSTEOSARCOMA,MAMMARY ADENOCARCINOMA,THYROID CARCINOMA
F008S30	465	12.5	12.9	477.	MAY-19-59	4832	30.5	UNDETERMINED (NO SKELETAL TUMOR)
F009S30	468	10.0	10.1	374.	AUG-11-59	4599	26.6	CHROMAPHOBE ADENOMA
M010S30	519	12.5	10.3	381.	SEP-29-59	2898	20.9	FIBROSARCOMA (SOFT TISSUE)
F011S30	541	9.00	10.8	400.	NOV-03-59	4831	9.54	NEPHRITIS
M012S30	605	8.43	10.2	377.	JAN-06-60	4831	16.3	TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
F001S40	468	8.74	33.3	1230.	JAN-18-55	3682	65.9	UNDETERMINED (NO SKELETAL TUMOR)
M002S40	567	11.2	32.6	1210.	FEB-14-56	2093	56.4	EPIDERMOID CARCINOMA (MOUTH)
M003S40	593	9.83	32.1	1190.	SEP-11-57	2781	41.2	THROMBOEMBOLISM
F004S40	528	8.24	32.1	1190.	OCT-15-57	4844	77.7	OSTEOSARCOMA, EPIDERMOID CARCINOMA (MOUTH)
M005S40	562	9.65	30.6	1130.	NOV-19-57	4427	62.6	HEMANGIOSARCOMA (SOFT TISSUE)
M006S40	504	16.0	32.7	1210.	SEP-03-58	3530	68.7	SEMINOMA
F007S40	478	10.9	30.9	1140.	NOV-11-58	4664	79.0	OSTEOSARCOMA
F008S40	465	10.9	40.6	1500.	MAY-19-59	2206	77.1	UNDETERMINED (NO SKELETAL TUMOR)
F009S40	468	9.56	30.6	1130.	AUG-11-59	4942	75.9	UNDETERMINED (NO SKELETAL TUMOR)
M010S40	517	8.20	31.3	1160.	SEP-29-59	4242	63.5	HEMANGIOMA, PERIANAL GLAND CARCINOMA
F011S40	542	8.86	32.7	1210.	NOV-03-59	2114	33.0	BLOOD DYSCRASIA, ENDOMETRITIS
M012S40	605	10.9	32.3	1200.	JAN-06-60	4226	52.8	NOSE ADENOCARCINOMA
F001S45	529	9.00	64.2	2380.	MAR-16-66	3030	73.7	PURPURA HEMORRHAGICA
M002S45	529	12.2	63.6	2350.	MAR-16-66	2707	72.2	OSTEOSARCOMA
M003S45	529	11.9	63.8	2360.	MAR-16-66	1493	58.9	ANEMIA, INFARCTION, MYELOID METAPLASIA
F004S45	529	9.80	64.5	2390.	MAR-16-66	2197	90.4	HEMANGIOSARCOMA (SOFT TISSUE)
M005S45	496	13.3	61.3	2270.	MAR-16-66	993	53.5	OSTEOSARCOMA
M006S45	496	12.0	63.8	2360.	MAR-16-66	2843	94.3	OSTEOSARCOMA
F007S45	510	9.90	64.5	2390.	MAR-16-66	2813	100.	OSTEOSARCOMA, EPIDERMOID CARCINOMA (FRONTAL SINUS)
F008S45	510	9.90	64.5	2390.	MAR-16-66	2325	94.8	HEMANGIOSARCOMA (SKELETON)
F009S45	510	10.3	64.0	2370.	MAR-16-66	1028	51.3	OSTEOSARCOMA
M010S45	496	14.0	60.9	2250.	MAR-16-66	2064	110.	EPIDERMOID CARCINOMA (FRONTAL SINUS)
F011S45	496	11.9	63.8	2360.	MAR-16-66	1758	63.8	OSTEOSARCOMA
M012S45	485	11.4	63.7	2360.	MAR-16-66	2253	97.7	OSTEOSARCOMA, HEMANGIOSARCOMA (SKELETON)
F001S50	434	9.38	103.	3810.	JAN-18-55	960	82.6	OSTEOSARCOMA

B.9 ^{90}Sr, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M002S50	551	12.2	102.	3770.	FEB-14-56	255	30.9	STRANGULATED HERNIA
M002S50A	545	11.4	96.6	3570.	JAN-07-59	1740	122.	OSTEOSARCOMA
M003S50	507	10.3	102.	3770.	OCT-15-57	2256	164.	OSTEOSARCOMA
F004S50	528	11.4	105.	3390.	OCT-15-57	1448	94.2	OSTEOSARCOMA
M005S50	621	8.53	95.2	3520.	NOV-19-57	1285	101.	ANEMIA, AUTOAGGLUTINATION, INFARCTION
M006S50	504	9.33	98.8	3660.	SEP-03-58	35	5.23	HEMORRHAGE (INTESTINE)
M006S50A	462	11.2	94.2	3490.	JAN-07-59	1021	114.	OSTEOSARCOMA, INFARCTION, THROMBOCYTOPENIA
F007S50	478	10.2	92.7	3430.	NOV-11-58	1129	108.	STATUS EPILEPTICUS
F008S50	535	11.2	90.5	3350.	JAN-07-59	1469	110.	OSTEOSARCOMA
F009S50	459	8.82	93.5	3460.	AUG-11-59	1982	135.	EPIDERMOID CARCINOMA (FRONTAL SINUS)
M010S50	517	8.55	95.9	3550.	SEP-29-59	990	75.4	ANEMIA, THROMBOCYTOPENIA
F011S50	542	8.97	102.	3770.	NOV-03-59	1667	99.2	HEMANGIOSARCOMA (SKELETON)
M012S50	606	12.5	99.2	3670.	JAN-06-60	1165	80.3	HEMANGIOSARCOMA (SKELETON)

B.10 ^{228}Th, Chronic Toxicity Study

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M001T00	493	8.24			FEB-08-54	4895		LYMPHOSARCOMA
M002T00	488	7.28			SEP-28-54	5510		INERSTITIAL NEPHRITIS
F003T00	797	11.6			JUN-06-55	2592		BRAIN HEMORRHAGE
M004T00	591	8.10			OCT-18-55	3072		LYMPHOSARCOMA
M005T00	458	10.4			OCT-14-58	5306		LYMPHOSARCOMA
F006T00	489	9.64			JAN-10-61	171		TRAUMA
F006T00A	688	8.61			DEC-15-60	4549		PERICARDITIS
M007T00	517	10.5			FEB-07-61	1412		HEMORRHAGE (BRAIN)
M008T00	533	10.8			MAY-24-61	4963		NEPHRITIS
F009T00	569	8.23			JUN-29-61	5061		TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
F010T00	536	10.4			JUL-28-61	4700		AORTIC BODY TUMOR
F011T00	530	9.45			JUN-04-63	4271		STATUS EPILEPTICUS
F012T00	492	9.09			JUL-09-63	4137		TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
M001T02	682	11.4	0.00164	0.0607	MAR-27-62	4837	0.13	LUNG CARCINOMA, MYELOID SARCOMA (LIVER)
M002T02	682	10.4	0.00166	0.0614	MAR-27-62	4822	0.13	MELANOMA (MOUTH), STOMACH CARCINOMA
F003T02	478	9.86	0.00163	0.0603	MAR-27-62	4720	0.13	STATUS EPILEPTICUS
M004T02	478	10.0	0.00166	0.0614	MAR-27-62	4515	0.13	TRANS. CELL CARC. (URINARY BLADDER),THROMBOEMBOLISM
M005T02	625	13.8	0.00162	0.0599	FEB-09-60	889	0.08	STRANGULATION ON VOMITUS, STATUS EPILEPTICUS
M005T02A	530	13.4	0.00173	0.0640	JUN-04-63	5609	0.14	SENILITY
F006T02	489	8.85	0.00176	0.0651	JAN-10-61	4767	0.14	ISLET CELL TUMOR
M007T02	532	10.5	0.00159	0.0588	FEB-07-61	3897	0.12	LYMPHOSARCOMA
M008T02	494	13.9	0.00189	0.0699	MAY-24-61	4826	0.15	LEIOMYOSARCOMA
F009T02	569	7.82	0.00171	0.0633	JUN-29-61	3897	0.13	THROMBOEMBOLISM
F010T02	508	10.5	0.00170	0.0629	JUL-28-61	4217	0.13	BILIARY OBSTRUCTION, MAMMARY ADENOCARCINOMA
F011T02	530	9.76	0.00171	0.0633	JUN-04-63	4573	0.14	BILIARY OBSTRUCTION, CHRONIC PANCREATITIS
F012T02	492	7.37	0.00190	0.0703	JUL-09-63	3350	0.15	HEPATIC CELL CARCINOMA
M001T05	699	14.3	0.00496	0.184	SEP-07-56	3471	0.39	HEMORRHAGE (BRAIN)
M002T05	455	10.5	0.00490	0.181	SEP-23-54	1976	0.35	STRANGULATION ON VOMITUS, STATUS EPILEPTICUS
F003T05	659	8.59	0.00485	0.179	JUN-06-55	3032	0.37	ENDOMETRITIS, PERITONITIS
M004T05	516	8.58	0.00540	0.200	OCT-18-55	2159	0.39	STATUS EPILEPTICUS, PNEUMONIA
M005T05	513	8.46	0.00522	0.193	OCT-14-58	4856	0.41	PROSTATITIS
F006T05	489	9.66	0.00510	0.189	JAN-10-61	4548	0.40	ISLET CELL TUMOR
M007T05	532	9.11	0.00491	0.182	FEB-07-61	5840	0.39	NEPHRITIS, PROSTATE ADENOCARCINOMA
M008T05	533	9.53	0.00562	0.208	MAY-24-61	4599	0.44	MELANOMA (ORAL)
F009T05	569	8.62	0.00529	0.196	JUN-29-61	4149	0.42	MAMMARY ADENOCARCINOMA
F010T05	508	10.2	0.00510	0.189	JUL-28-61	4947	0.40	OSTEOSARCOMA, THYROID ADENOCARCINOMA
F011T05	530	7.78	0.00518	0.192	JUN-04-63	3952	0.41	THROMBOEMBOLISM, ISLET CELL ADENOCARCINOMA
F012T05	492	9.94	0.00567	0.210	JUL-09-63	1682	0.39	DEGENERATION (LIVER), ANESTHESIA ACCIDENT
M001T10	493	9.36	0.0140	0.518	FEB-08-54	3172	1.13	OSTEOSARCOMA
M002T10	699	9.27	0.0146	0.540	SEP-07-56	4570	1.15	PERIANAL GLAND CARCINOMA
F003T10	723	8.84	0.0145	0.537	SEP-07-56	4142	1.14	MYELOID SARCOMA (LIVER)
M004T10	699	8.27	0.0146	0.540	SEP-07-56	3217	1.13	OSTEOSARCOMA, ADENOCARCINOMA (THYROID+PERIANAL GLAND)
M005T10	513	11.9	0.0146	0.540	OCT-14-58	2886	1.12	STATUS EPILEPTICUS
F006T10	489	8.81	0.0150	0.555	JAN-10-61	3273	1.17	PERFORATION (STOMACH)

B.10 ^{228}Th, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M007T10	532	9.18	0.0147	0.544	FEB-07-61	3538	1.15	OSTEOSARCOMA
M008T10	533	8.69	0.0166	0.614	MAY-24-61	5298	1.32	LUNG CARCINOMA, NEPHRITIS
F009T10	527	10.0	0.0160	0.592	JUN-29-61	2546	1.20	LEIOMYOSARCOMA
F010T10	508	10.2	0.0150	0.555	JUL-28-61	3420	1.17	FIBROSARCOMA (BONE)
F011T10	520	7.55	0.0154	0.570	JUN-04-63	4034	1.21	OSTEOSARCOMA
F012T10	471	9.96	0.0167	0.618	JUL-09-63	1263	1.01	PNEUMONIA
M001T15	699	7.95	0.0289	1.07	SEP-07-56	2894	2.22	OSTEOSARCOMA
M002T15	458	10.0	0.0293	1.08	SEP-28-54	2576	2.21	OSTEOSARCOMA
F003T15	699	10.3	0.0303	1.12	JUN-06-55	1921	2.14	COMA (NO SKELETAL TUMOR)
M004T15	591	8.59	0.0299	1.11	OCT-18-55	2309	2.21	HEMANGIOSARCOMA
M005T15	598	9.65	0.0286	1.06	FEB-09-60	1624	1.92	OSTEOSARCOMA
F006T15	489	8.14	0.0292	1.03	JAN-10-61	2373	2.17	OSTEOSARCOMA
M007T15	517	8.83	0.0292	1.08	FEB-07-61	383	0.78	LEPTOSPIROSIS
M007T15A	520	9.08	0.0311	1.15	JUN-04-63	3110	2.40	OSTEOSARCOMA, PNEUMONIA
M008T15	494	11.6	0.0324	1.20	MAY-24-61	2665	2.46	OSTEOSARCOMA
F009T15	527	8.80	0.0306	1.13	JUN-29-61	2983	2.35	CHONDROSARCOMA
F010T15	508	11.6	0.0296	1.10	JUL-28-61	1859	2.08	OSTEOSARCOMA
F011T15	518	11.4	0.0305	1.13	JUN-04-63	2408	2.27	OSTEOSARCOMA
F012T15	464	7.56	0.0329	1.22	JUL-09-63	2120	2.39	OSTEOSARCOMA
M001T20	490	10.2	0.0976	3.61	FEB-08-54	1282	5.97	OSTEOSARCOMA
M002T20	483	9.16	0.0875	3.24	SEP-28-54	1234	5.26	OSTEOSARCOMA
F003T20	474	7.87	0.0908	3.36	JUN-06-55	1541	5.99	OSTEOSARCOMA
M004T20	552	13.0	0.0900	3.33	OCT-18-55	78	0.52	TRAUMA
M004T20A	650	10.6	0.0899	3.33	SEP-07-56	1222	5.37	OSTEOSARCOMA
M005T20	598	9.12	0.0848	3.14	FEB-09-60	1085	4.78	OSTEOSARCOMA
F006T20	451	8.65	0.0879	3.25	JAN-10-61	1108	5.01	OSTEOSARCOMA
M007T20	517	8.85	0.0881	3.26	FEB-07-61	1015	4.79	OSTEOSARCOMA
M008T20	533	10.7	0.0981	3.63	MAY-24-61	1078	5.51	OSTEOSARCOMA
F009T20	527	8.09	0.0979	3.62	JUN-29-61	1209	5.82	OSTEOSARCOMA
F010T20	507	10.7	0.0919	3.40	JUL-28-61	1022	5.02	OSTEOSARCOMA
F011T20	518	10.8	0.0904	3.34	JUN-04-63	1038	4.98	OSTEOSARCOMA
F012T20	463	8.92	0.100	3.70	JUL-09-63	1449	6.44	OSTEOSARCOMA
M001T30	314	9.15	0.301	11.1	FEB-08-54	988	16.9	OSTEOSARCOMA, ANEMIA
M002T30	458	11.9	0.301	11.1	SEP-28-54	859	15.6	GIANT CELL TUMOR, (BONE) TRAUMA
F003T30	471	12.0	0.272	10.1	JUN-06-55	547	10.2	OSTEOSARCOMA
M004T30	606	9.69	0.285	10.5	OCT-18-55	801	14.1	OSTEOSARCOMA
M005T30	571	10.7	0.269	9.95	FEB-09-60	890	14.2	OSTEOSARCOMA
F006T30	451	8.83	0.282	10.4	JAN-10-61	1156	17.2	OSTEOSARCOMA
M007T30	427	9.90	0.266	9.84	FEB-07-61	861	13.8	OSTEOSARCOMA
M008T30	494	10.1	0.313	11.6	MAY-24-61	685	13.9	OSTEOSARCOMA
F009T30	511	11.5	0.298	11.0	JUN-29-61	1062	17.4	OSTEOSARCOMA
F010T30	507	9.26	0.280	10.4	JUL-28-61	971	15.6	OSTEOSARCOMA
F011T30	518	10.3	0.290	10.7	JUN-04-63	826	14.6	OSTEOSARCOMA
F012T30	458	11.5	0.320	11.8	JUL-09-63	804	15.9	HEMANGIOSARCOMA (SKELETON)

B.10 ^{228}Th, Chronic Toxicity Study (continued)

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
M001T40	479	8.32	0.882	32.6	FEB-08-54	645	38.9	OSTEOSARCOMA, CRIPPLING FRACTURE
M002T40	458	8.32	0.916	33.9	SEP-28-54	833	48.1	OSTEOSARCOMA, CRIPPLING FRACTURE, NEPHRITIS
F003T40	460	7.25	0.800	29.6	JUN-06-55	763	39.7	ULCER (MOUTH), NEPHRITIS
M004T40	606	8.81	0.835	30.9	OCT-18-55	793	42.5	ULCER (MOUTH)
M001T50	479	9.48	2.76	102.	FEB-08-54	212	45.7	KIDNEY DEGENERATION
M002T50	483	8.22	2.63	97.3	SEP-28-54	97	.7	PANCYTOPENIA

B.11 ^{241}Am, Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T158W00	553	12.9			DEC-30-76	4292		SPECIAL STUDY
T159W00	546	10.6			DEC-30-76	3555		SPECIAL STUDY
T160W10	577	11.4	0.0159	0.588	DEC-30-76	4408	0.63	FIBROSARCOMA (LIVER)
T161W10	546	11.9	0.0159	0.588	DEC-30-76	1802	0.26	PNEUMONIA
T162W10	546	9.64	0.0164	0.607	DEC-30-76	3770	0.57	CHOLANGIOCARCINOMA
T163W10	544	9.32	0.0162	0.599	DEC-30-76	4863	0.88	SPECIAL STUDY
T164W17	553	11.3	0.0481	1.78	DEC-30-76	3366	1.69	CHOLANGIOCARCINOMA, HEPATIC CELL CARCINOMA
T165W17	546	8.73	0.0488	1.81	DEC-30-76	1810	0.84	PNEUMONIA
T166W17	544	9.28	0.0480	1.78	DEC-30-76	3452	1.59	SPECIAL STUDY
T167W17	544	9.04	0.0482	1.78	DEC-30-76	3340	1.69	CHOLANGIOCARCINOMA
T102W30	515	11.6	0.280	10.4	OCT-10-72	17	0.05	SPECIAL STUDY
T103W30	501	10.6	0.283	10.5	OCT-10-72	2535	6.27	OSTEOSARCOMA,HEMANGIOSARC. (LIVER),FIBROSARC. (LIVER)
T104W30	2658	7.67	0.305	11.3	NOV-28-72	1864	5.18	EMPYEMA
T105W30	2225	7.78	0.301	11.1	NOV-28-72	1100	4.77	FIBROSARCOMA (SOFT TISSUE), DEGENERATION (KIDNEY)
T106W30	2225	13.8	0.308	11.4	NOV-28-72	1909	5.84	TRAUMA
T108W30	507	12.6	0.304	11.2	AUG-08-73	3673	1.08	ENDOMETRITIS, SEPTICEMIA
T109W30	506	9.90	0.305	11.3	AUG-08-73	3960	2.63	PNEUMONIA
T110W30	506	9.30	0.306	11.3	AUG-08-73	1506	1.32	ANESTHESIA ACCIDENT, ADRENOCORTICAL HYPOPLASIA
T111W30	506	9.81	0.303	11.2	AUG-08-73	4774	1.06	SPECIAL STUDY
T112W30	506	6.92	0.333	12.3	OCT-23-73	44	0.14	INTUSSUSCEPTION
T113W30	499	9.35	0.333	12.3	OCT-23-73	3760	2.00	HEMANGIOSARCOMA (SOFT TISSUE)
T114W30	531	12.9	0.300	11.1	JUL-02-74	1505	5.18	OSTEOSARCOMA
T142W30	586	9.76	0.299	11.1	JAN-28-76	2504	1.96	OSTEOSARCOMA
T143W30	533	9.21	0.317	11.7	FEB-04-76	2421	6.62	OSTEOSARCOMA
T146W30	593	7.07	0.301	11.1	FEB-13-76	3098	1.00	ENTERITIS
T154W30	535	9.96	0.287	10.6	AUG-04-76	21	0.08	SPECIAL STUDY
T155W30	532	10.2	0.280	10.4	AUG-04-76	2380	1.97	ENCEPHALOPATHY
T156W30	528	10.0	0.286	10.6	AUG-04-76	3654	2.46	SPECIAL STUDY
T157W30	526	9.99	0.286	10.6	AUG-04-76	23	0.07	SPECIAL STUDY
T175W30+	3662	13.0	0.238	8.81	SEP-20-83	1554	4.04	UNDETERMINED
T176W30+	3726	9.35	0.330	12.2	SEP-20-83	415	0.72	MAMMARY ADENOCARCINOMA
T177W30	687	14.3	0.216	7.99	SEP-20-83	2240	1.26	SPECIAL STUDY
T178W30	687	10.5	0.294	10.9	SEP-20-83	2240	1.72	SPECIAL STUDY
T181W30	2267	9.60	0.310	11.5	MAR-26-86	9	0.03	SPECIAL STUDY
T182W30	1775	10.6	0.280	10.4	APR-04-86	10	0.03	SPECIAL STUDY
T183W30	3512	8.90	0.340	12.6	APR-21-86	9	0.03	SPECIAL STUDY
T184W30	2269	11.0	0.270	9.99	APR-22-86	10	0.03	SPECIAL STUDY
T185W30	1179	8.60	0.350	13.0	MAY-07-86	9	0.03	SPECIAL STUDY
T186W30	1116	9.80	0.310	11.5	MAY-12-86	9	0.03	SPECIAL STUDY
T117W40	385	9.98	1.20	44.4	NOV-19-74	1416	16.6	OSTEOSARCOMA
T118W40	385	8.96	1.34	49.6	NOV-19-74	3330	2.17	UNDETERMINED (NO SKELETAL TUMOR)
T119W40	385	8.36	1.44	53.3	NOV-19-74	3252	1.30	PNEUMONIA
T144W40	397	11.8	0.804	29.7	MAY-19-76	545	5.20	SPECIAL STUDY
T145W40	397	11.6	0.983	36.4	MAY-19-76	545	6.34	SPECIAL STUDY

B.11 ^{241}Am, Test Studies (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T168W40	997	9.80	0.976	36.1	JUN-21-78	7	0.07	SPECIAL STUDY
T169W40	934	10.4	0.919	34.0	JUN-21-78	7	0.06	SPECIAL STUDY
T170W40	986	10.2	0.937	34.7	JUN-21-78	7	0.05	SPECIAL STUDY
T171W40	856	9.00	1.06	39.2	JUN-21-78	7	0.04	SPECIAL STUDY
T172W40	976	11.6	0.824	30.5	JUN-21-78	7	0.04	SPECIAL STUDY
T173W40	933	11.7	0.817	30.2	JUN-20-78	8	0.07	SPECIAL STUDY
T174W40	994	8.50	1.12	41.4	JUN-18-78	10	0.11	SPECIAL STUDY
T179W40Y	87	3.45	0.896	33.2	OCT-11-83	2220	2.64	SPECIAL STUDY
T180W40Y	87	3.65	0.846	31.3	OCT-11-83	2220	2.49	SPECIAL STUDY
T016W50	461	10.7	2.78	103.	JAN-29-68	22	0.50	SPECIAL STUDY
T056W50	552	11.3	2.90	107.	NOV-25-69	15	0.48	SPECIAL STUDY
T057W50	496	7.01	2.77	102.	JAN-26-70	15	0.41	SPECIAL STUDY
T099W50	547	11.3	2.67	98.8	NOV-10-70	252	7.13	SPECIAL STUDY
T101W50	399	10.4	2.98	110.	AUG-17-72	1	0.03	SPECIAL STUDY
T107W50	3542	9.24	2.34	85.6	APR-02-73	35	0.81	MELANOMA (MOUTH)
T120W50	2894	8.77	3.17	117.	FEB-24-75	283	10.2	DEGENERATION (LIVER AND KIDNEY)
T147W50N	1	0.25	3.11	115.	FEB-01-76	1	0.06	SPECIAL STUDY
T148W50N	1	0.26	2.97	110.	FEB-01-76	3	0.21	SPECIAL STUDY
T149W50N	1	0.27	2.88	107.	FEB-01-76	5	0.33	SPECIAL STUDY
T150W50N	1	0.28	2.79	103.	FEB-01-76	5	0.32	SPECIAL STUDY
T151W50N	1	0.24	3.20	118.	FEB-01-76	1	0.06	SPECIAL STUDY
T152W50N	1	0.25	3.11	115.	FEB-01-76	1	0.07	SPECIAL STUDY
T153W50N	1	0.27	2.84	105.	FEB-01-76	3	0.18	SPECIAL STUDY
Y015W55	858	11.5	4.53	168.	OCT-23-67	1	0.04	SPECIAL STUDY
T032W55	553	11.0	4.46	165.	APR-30-68	7	0.27	SPECIAL STUDY
T033W55	393	10.5	4.47	165.	APR-30-68	8	0.33	SPECIAL STUDY

B.12 ^{210}Bi, Test Studies

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTION: INJECTED (UCI/KG)	INJECTION: INJECTED (KBQ/KG)	INJECTION: DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T001030	695	10.9	8.00	296	AUG-06-80	1	0.01	SPECIAL STUDY
T002030	676	10.4	7.95	294	AUG-07-80	2/24	0.01	SPECIAL STUDY
T003030	603	9.02	7.70	285	AUG-19-80	1	0.01	SPECIAL STUDY
T004030	681	9.95	8.40	311	AUG-27-80	2/24	0.01	SPECIAL STUDY
T005030	1338	10.8	11.0	407	JAN-06-82	1	0.01	SPECIAL STUDY
T006030	1264	11.2	7.08	262	JAN-13-82	2/24	0.01	SPECIAL STUDY

B.13 ^{249}Cf, Test Studies

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T001G50	597	12.2	2.84	105	FEB-24-71	500	20.2	NEPHRITIS,MYOCARDIAL INFARCTION
T002G50	584	10.7	2.77	102	FEB-24-71	7	0.29	SPECIAL STUDY
T003G50	584	9.85	2.80	104	FEB-24-71	21	0.82	SPECIAL STUDY

B.14 ^{252}Cf, Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T001F50	586	11.4	2.81	104	SEP-08-71	36	2.87	SPECIAL STUDY
T002F50	540	10.7	2.87	106	NOV-17-71	13	1.04	SPECIAL STUDY

B.15 $^{243,244}Cm$, Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T007C30	596	8.38	0.308	11.4	APR-29-80	7	0.03	SPECIAL STUDY
T008C30	596	8.43	0.306	11.3	APR-29-80	28	0.12	SPECIAL STUDY
T009C30	576	9.47	0.310	11.5	APR-29-80	111	0.42	SPECIAL STUDY
T001C50	511	10.4	2.60	96.2	FEB-27-73	1142	35.5	DEGENERATION (LIVER AND KIDNEY)
T002C50	485	12.2	2.64	97.7	FEB-27-73	6	0.21	SPECIAL STUDY
T003C50	485	11.4	2.64	97.7	FEB-27-73	13	0.46	SPECIAL STUDY
T004C50	485	12.5	2.64	97.7	FEB-27-73	20	0.71	SPECIAL STUDY
T005C50	485	12.8	2.63	97.3	FEB-27-73	384	13.0	DEGENERATION (LIVER)
T006C50	498	10.7	2.90	107.	OCT-22-73	87	2.88	SPECIAL STUDY

B.16 ^{253}Es, Test Studie.

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T001E50	470	9.82	2.87	106	JUN-05-73	7	0.20	SPECIAL STUDY
T002E50	483	12.2	2.89	107	JUN-05-73	21	0.77	SPECIAL STUDY
T003E50	483	11.0	2.84	105	JUN-05-73	55	1.38	SPECIAL STUDY
T004E50	484	12.3	2.97	110	JUN-06-73	2420	1.60	ABSCESS (LUNG), EMPYEMA
T005E50	484	11.2	2.93	108	SEP-10-73	7	0.34	SPECIAL STUDY

B.17 ^{210}Pb, Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T001D30	695	10.9	8.00	296	AUG-06-80	1	0.01	SPECIAL STUDY
T002D30	676	10.4	7.95	294	AUG-07-80	2/24	0.01	SPECIAL STUDY
T003D30	603	9.02	7.70	285	AUG-19-80	1	0.01	SPECIAL STUDY
T004D30	681	9.95	8.40	311	AUG-27-80	2/24	0.01	SPECIAL STUDY
T005D30	1338	10.8	11.0	407	JAN-06-82	1	0.01	SPECIAL STUDY
T006D30	1264	11.2	7.08	262	JAN-13-82	2/24	0.01	SPECIAL STUDY

B.18 ^{237}Pu or ^{241}Pu, Test Studies

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T001K10	520	9.53	0.0286	1.06	DEC-10-74	13	0.01	SPECIAL STUDY
T002K10	517	10.3	0.0266	0.984	DEC-10-74	20	0.01	SPECIAL STUDY
T003K10	517	9.72	0.0281	1.04	DEC-10-74	27	0.01	SPECIAL STUDY
T021K17	515	9.80	504.	18648.	FEB-28-80	7	0.20	SPECIAL STUDY
T022K17Y	92	4.35	369.	13653.	APR-08-80	2	0.04	SPECIAL STUDY
T023K17Y	89	3.47	462.	17094.	APR-08-80	21	1.03	SPECIAL STUDY
T024K17	542	12.2	507.	18759.	JUL-30-81	6	0.17	SPECIAL STUDY

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T001K10 THROUGH T003K10 WERE INJECTED WITH PU-237.
T002K17 THROUGH T024K17 WERE INJECTED WITH PU-241.

B.19 ^{239}Pu, Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T022P00								REASSIGNED, SEE F006T00A
T064P00								REASSIGNED, SEE T124P17
T090P00	487	7.60			MAY-06-75	378		SPECIAL STUDY
T105P00	574	11.8			FEB-23-76	11		SPECIAL STUDY
T108P00	581	10.3			FEB-06-76	14		SPECIAL STUDY
T109P00	581	8.50			FEB-13-76	4		SPECIAL STUDY
T110P00	579	9.31			FEB-12-76	7		SPECIAL STUDY
T114P00	555	9.25			FEB-26-76	18		SPECIAL STUDY
T115P00	570	13.2			MAR-12-76	4		SPECIAL STUDY
T180P00	502	9.78			FEB-24-77	27		SPECIAL STUDY
T182P00	518	8.52			MAR-24-77	56		SPECIAL STUDY
T183P00	516	11.3			APR-14-77	28		SPECIAL STUDY
T201P00	579	8.95			OCT-04-77	29		SPECIAL STUDY
T258P00E	557	55.5			AUG-03-82	1645		SPECIAL STUDY
T259P00E	557	58.5			AUG-03-82	1645		SPECIAL STUDY
T260P00E	557	60.3			AUG-03-82	1647		SPECIAL STUDY
T275P00+	1810	11.2			JAN-21-86	28		SPECIAL STUDY
T276P00+	1825	11.1			JAN-21-86	224		SPECIAL STUDY
T277P00+	1825	11.2			JAN-21-86	455		SPECIAL STUDY
T083P01E	575	51.3	0.00061	0.0226	AUG-22-73	2390	0.01	ARTHRITIS
T084P01E	517	55.7	0.00066	0.0244	FEB-19-75	3761	0.02	DIGESTIVE DISORDER
T085P01E	557	52.0	0.00071	0.0263	APR-01-75	2372	0.01	LYMPHOSARCOMA
T080P02E	569	48.7	0.00153	0.0566	JUL-25-73	3381	0.04	UNDETERMINED (NO TUMOR)
T081P02E	569	44.3	0.00157	0.0581	JUL-25-73	3709	0.04	OSTEOSARCOMA
T082P02E	597	47.2	0.00191	0.0707	AUG-22-73	3702	0.05	MAST CELL SARCOMA
T071P05E	588	48.9	0.00521	0.193	MAY-09-72	3011	0.12	THROMBOEMBOLISM
T072P05E	611	44.5	0.00512	0.189	JUN-01-72	2851	0.12	ACARIAN DERMATITIS
T073P05E	611	38.8	0.00507	0.188	JUN-01-72	3371	0.13	EMPYEMA, ISLET CELL TUMOR
T079P05	483	11.1	0.00523	0.194	JUN-05-73	134	0.01	SPECIAL STUDY
T252P05E	530	44.4	0.00494	0.183	NOV-17-81	2509		BATTELLE LABS
T253P05E	530	46.4	0.00494	0.183	NOV-17-81	2509	0.10	BATTELLE LABS - DEAD (NO CAUSE REC'D)
T254P05E	558	42.0	0.00490	0.181	DEC-15-81	2481	0.10	BATTELLE LABS - DEAD (NO CAUSE REC'D)
T023P10	1485	13.1	0.0172	0.636	JUL-28-61	96	0.02	SPECIAL STUDIES
T024P10	559	13.1	0.0172	0.636	JUL-28-61	97	0.02	SPECIAL STUDY
T025P10	559	13.8	0.0167	0.618	JUL-28-61	467	0.09	SPECIAL STUDY
T026P10	556	12.0	0.0160	0.592	JUL-28-61	647	0.11	SPECIAL STUDY
T028P10	552	10.5	0.0150	0.555	AUG-09-61	559	0.09	SPECIAL STUDY
T030P10	548	12.4	0.0148	0.548	AUG-09-61	35	0.01	SPECIAL STUDY
T032P10	519	8.47	0.0162	0.599	AUG-09-61	274	0.05	SPECIAL STUDY
T033P10	550	10.7	0.0153	0.566	SEP-15-61	375	0.07	SPECIAL STUDY
T034P10	550	9.68	0.0154	0.570	SEP-15-61	746	0.12	SPECIAL STUDY
T036P10	544	10.4	0.0158	0.585	SEP-15-61	5	0.01	SPECIAL STUDY
T037P10	542	8.59	0.0148	0.548	SEP-15-61	186	0.03	SPECIAL STUDY
T039P10	1534	10.7	0.0151	0.559	SEP-15-61	376	0.06	SPECIAL STUDY

B.19 ^{239}Pu, Test Studies (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T040P10	1534	9.92	0.0177	0.655	SEP-15-61	769	0.13	SPECIAL STUDY
T049P10	102	5.09	0.0162	0.599	JUL-05-66	5400	0.43	SENILITY
T068P10E	569	44.2	0.0158	0.585	APR-20-72	2393	0.31	OSTEOSARCOMA
T069P10E	569	32.0	0.0160	0.592	APR-20-72	3338	0.41	OSTEOSARCOMA
T070P10E	538	40.6	0.0152	0.562	MAY-09-72	3109	0.37	MANGE (DEMODECTIC), THROMBOEMBOLISM
T089P10	490	8.99	0.0176	0.651	MAY-06-75	379	0.08	SPECIAL STUDY
T091P10	488	10.6	0.0134	0.496	MAY-13-75	7	0.01	SPECIAL STUDY
T092P10	488	10.8	0.0134	0.496	MAY-13-75	29	0.01	SPECIAL STUDY
T093P10	483	9.04	0.0144	0.533	MAY-13-75	133	0.02	SPECIAL STUDY
T094P10	500	11.1	0.0166	0.614	MAY-28-75	27	0.01	SPECIAL STUDY
T095P10	511	9.46	0.0178	0.659	JUN-05-75	60	0.01	SPECIAL STUDY
T096P10	501	10.9	0.0159	0.588	JUL-08-75	7	0.01	SPECIAL STUDY
T097P10	490	13.0	0.0164	0.607	JUN-10-75	211	0.04	SPECIAL STUDY
T098P10	490	11.5	0.0162	0.599	JUN-10-75	209	0.04	SPECIAL STUDY
T099P10	497	10.9	0.0151	0.559	JUN-17-75	15	0.01	SPECIAL STUDY
T100P10	487	13.0	0.0155	0.574	JUN-24-75	363	0.07	SPECIAL STUDY
T101P10	490	10.0	0.0158	0.585	AUG-22-75	56	0.01	SPECIAL STUDY
T102P10	494	11.7	0.0152	0.562	AUG-26-75	140	0.03	SPECIAL STUDY
T103P10	490	8.97	0.0157	0.581	SEP-05-75	14	0.01	SPECIAL STUDY
T181P10	518	8.44	0.0162	0.599	MAR-24-77	33	0.01	SPECIAL STUDY
T184P10	516	9.60	0.0168	0.622	APR-14-77	56	0.01	SPECIAL STUDY
T202P10	587	7.67	0.0173	0.640	OCT-12-77	27	0.01	SPECIAL STUDY
T218P10W	611	10.2	0.0116	0.429	OCT-25-78	7	0.01	SPECIAL STUDY
T248P10E	539	56.6	0.0154	0.570	MAR-11-81	2760	0.34	DEAD (NO CAUSE REC'D) - BATTELLE LABS
T261P10+	1834	10.0	0.0162	0.599	NOV-19-85	182	0.04	SPECIAL STUDY
T262P10+	1836	8.77	0.0161	0.596	NOV-21-85	182	0.04	SPECIAL STUDY
T263P10+	1825	11.7	0.0160	0.592	JAN-21-86	112	0.02	SPECIAL STUDY
T264P10+	1837	8.81	0.0160	0.592	JAN-23-86	112	0.02	SPECIAL STUDY
T265P10+	1834	10.4	0.0159	0.588	FEB-18-86	14	0.01	SPECIAL STUDY
T266P10+	1836	14.5	0.0160	0.592	FEB-20-86	14	0.01	SPECIAL STUDY
T278P10	595	10.8	0.0213	0.788	JAN-21-86	77	0.02	SPECIAL STUDY
T279P10	597	14.4	0.0160	0.592	JAN-23-86	56	0.01	SPECIAL STUDY
T280P10	561	11.1	0.0160	0.592	FEB-25-86	14	0.01	SPECIAL STUDY
T281P10	563	10.2	0.0161	0.596	FEB-27-86	14	0.01	SPECIAL STUDY
T292P10	577	9.80	0.0164	0.607	MAR-13-86	448	0.08	SPECIAL STUDY
T104P17	565	7.75	0.0477	1.76	JAN-16-76	11	0.01	SPECIAL STUDY
T106P17	585	8.84	0.0455	1.68	FEB-06-76	3	0.01	SPECIAL STUDY
T107P17	581	9.35	0.0451	1.67	FEB-06-76	7	0.01	SPECIAL STUDY
T111P17	578	8.56	0.0433	1.60	FEB-11-76	14	0.01	SPECIAL STUDY
T112P17	589	8.90	0.0435	1.61	FEB-23-76	4	0.01	SPECIAL STUDY
T113P17	548	10.6	0.0438	1.62	FEB-19-76	18	0.01	SPECIAL STUDY
T124P17	2558	7.68	0.0527	1.95	MAY-13-76	118	0.07	SPECIAL STUDY
T226P17W	625	8.65	0.0319	1.18	JUN-06-79	7	0.01	SPECIAL STUDY
T227P17W	615	8.65	0.0319	1.18	JUN-06-79	7	0.01	SPECIAL STUDY

B.19 ^{239}Pu, Test Studies (continued)

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
	INJECTION							
T228P17W	625	8.45	0.0327	1.21	JUN-06-79	7	0.01	SPECIAL STUDY
T229P17W	615	9.30	0.0297	1.10	JUN-06-79	7	0.01	SPECIAL STUDY
T230P17W	695	9.95	0.0277	1.02	JUN-06-79	7	0.01	SPECIAL STUDY
T231P17W	591	7.75	0.0356	1.32	JUN-06-79	7	0.01	SPECIAL STUDY
T244P17W	667	12.5	0.0153	0.566	JUL-29-80	7	0.01	SPECIAL STUDY
T245P17W	667	13.6	0.0140	0.518	JUL-29-80	7	0.01	SPECIAL STUDY
T057P20E	618	49.4	0.0961	3.56	SEP-10-69	1506	1.35	OSTEOSARCOMA
T061P20E	580	47.2	0.0983	3.64	JAN-06-70	1639	1.47	OSTEOSARCOMA
T062P20E	583	52.5	0.156	5.77	JAN-22-70	1223	1.86	OSTEOSARCOMA
T117P20Y	96	3.79	0.108	4.00	JAN-15-76	7	0.01	SPECIAL STUDY
T118P20Y	96	3.87	0.105	3.89	JAN-15-76	14	0.02	SPECIAL STUDY
T119P20Y	84	4.42	0.0922	3.41	JAN-15-76	28	0.06	SPECIAL STUDY
T120P20Y	96	4.85	0.0840	3.11	JAN-15-76	56	0.11	SPECIAL STUDY
T121P20Y	84	3.64	0.112	4.14	JAN-15-76	119	0.14	SPECIAL STUDY
T122P20Y	96	3.69	0.110	4.07	JAN-15-76	89	0.13	SPECIAL STUDY
T123P20	2416	10.5	0.0882	3.26	MAR-05-76	14	0.01	SPECIAL STUDY
T125P20N	2	0.32	0.127	4.70	JUN-22-76	3	0.01	SPECIAL STUDY
T126P20N	2	0.29	0.160	5.92	JUN-22-76	3	0.01	SPECIAL STUDY
T127P20N	2	0.31	0.148	5.48	JUL-19-76	1	0.01	SPECIAL STUDY
T128P20N	2	0.30	0.153	5.66	JUL-19-76	1	0.01	SPECIAL STUDY
T129P20N	2	0.28	0.197	7.29	JUL-19-76	1	0.01	SPECIAL STUDY
T154P20N	2	0.20	0.154	5.70	NOV-09-76	7	0.01	SPECIAL STUDY
T155P20N	2	0.20	0.151	5.59	NOV-09-76	7	0.01	SPECIAL STUDY
T156P20N	2	0.28	0.0897	3.32	NOV-09-76	7	0.01	SPECIAL STUDY
T158P20	695	9.68	0.0866	3.20	JAN-11-77	14	0.02	SPECIAL STUDY
T159P20	700	10.7	0.0783	2.90	JAN-11-77	14	0.01	SPECIAL STUDY
T160P20	689	8.71	0.0962	3.56	JAN-11-77	14	0.02	SPECIAL STUDY
T161P20	700	10.4	0.0806	2.98	JAN-11-77	14	0.01	SPECIAL STUDY
T162P20	686	9.59	0.0874	3.23	JAN-11-77	14	0.02	SPECIAL STUDY
T163P20	686	10.6	0.0791	2.93	JAN-11-77	14	0.01	SPECIAL STUDY
T164P20	686	10.0	0.0838	3.10	JAN-11-77	14	0.02	SPECIAL STUDY
T165P20	695	10.4	0.0806	2.98	JAN-11-77	14	0.01	SPECIAL STUDY
T166P20	707	9.27	0.0904	3.34	FEB-01-77	14	0.02	SPECIAL STUDY
T167P20	707	12.6	0.0665	2.46	FEB-01-77	14	0.01	SPECIAL STUDY
T168P20	707	9.39	0.0893	3.30	FEB-01-77	14	0.02	SPECIAL STUDY
T169P20	699	10.9	0.0769	2.85	FEB-01-77	14	0.01	SPECIAL STUDY
T170P20	699	10.8	0.0776	2.87	FEB-01-77	14	0.01	SPECIAL STUDY
T171P20	710	11.3	0.0742	2.75	FEB-01-77	14	0.01	SPECIAL STUDY
T172P20	699	9.79	0.0856	3.17	FEB-01-77	14	0.02	SPECIAL STUDY
T173P20	707	10.4	0.0806	2.98	FEB-01-77	14	0.01	SPECIAL STUDY
T174P20Y	93	3.52	0.0989	3.66	FEB-08-77	903	0.55	SPECIAL STUDY
T175P20Y	93	3.14	0.0936	3.46	FEB-08-77	512	0.34	SPECIAL STUDY
T176P20Y	93	2.89	0.0953	3.53	FEB-08-77	360	0.26	SPECIAL STUDY
T177P20Y	92	4.01	0.0981	3.63	FEB-08-77	364	0.27	SPECIAL STUDY

B.19 ^{239}Pu, Test Studies (continued)

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
	INJECTION							
T178P20Y	92	4.34	0.0969	3.59	FEB-08-77	513	0.35	SPECIAL STUDY
T179P20Y	92	3.60	0.0967	3.58	FEB-08-77	669	0.43	SPECIAL STUDY
T185P20Y	90	3.31	0.0941	3.48	MAR-09-78	182	0.16	SPECIAL STUDY
T186P20Y	88	3.71	0.0918	3.40	MAY-09-78	86	0.09	SPECIAL STUDY
T187P20Y	92	3.20	0.0994	3.68	NOV-21-78	28	0.03	SPECIAL STUDY
T188P20Y	88	3.32	0.0988	3.66	NOV-21-78	128	0.13	SPECIAL STUDY
T201P20	580	10.9	0.0826	3.06	SEP-05-78	7	0.01	SPECIAL STUDY
T204P20	563	7.70	0.117	4.33	SEP-06-78	7	0.01	SPECIAL STUDY
T205P20	520	9.55	0.0943	3.49	SEP-07-78	7	0.01	SPECIAL STUDY
T206P20	1282	11.2	0.0804	2.97	AUG-24-78	7	0.01	SPECIAL STUDY
T207P20	942	9.20	0.0979	3.62	AUG-24-78	7	0.01	SPECIAL STUDY
T208P20	942	10.9	0.0827	3.06	AUG-24-78	7	0.01	SPECIAL STUDY
T209P20	940	9.80	0.0919	3.40	AUG-24-78	7	0.01	SPECIAL STUDY
T210P20	920	9.25	0.0974	3.60	AUG-24-78	7	0.01	SPECIAL STUDY
T211P20	1295	7.40	0.122	4.51	AUG-23-78	8	0.01	SPECIAL STUDY
T212P20	802	8.80	0.103	3.81	AUG-21-78	10	0.01	SPECIAL STUDY
T213P20W	553	9.50	0.0703	2.60	OCT-10-78	7	0.01	SPECIAL STUDY
T214P20W	553	9.00	0.0742	2.75	OCT-10-78	7	0.01	SPECIAL STUDY
T215P20W	553	8.60	0.0777	2.87	OCT-10-78	7	0.01	SPECIAL STUDY
T216P20W	537	11.4	0.0586	2.17	OCT-10-78	7	0.01	SPECIAL STUDY
T217P20W	537	9.40	0.0711	2.53	OCT-10-78	7	0.01	SPECIAL STUDY
T219P20W	904	12.0	0.0731	2.70	DEC-01-78	32	0.08	SPECIAL STUDY
T220P20W	904	11.3	0.0776	2.87	DEC-01-78	42	0.11	SPECIAL STUDY
T221P20W	806	9.36	0.0938	3.47	DEC-01-78	35	0.11	SPECIAL STUDY
T232P20W	568	10.4	0.102	3.77	SEP-13-79	7	0.01	SPECIAL STUDY
T233P20W	550	12.0	0.0832	3.26	SEP-13-79	7	0.01	SPECIAL STUDY
T234P20W	540	11.6	0.0913	3.38	SEP-13-79	7	0.01	SPECIAL STUDY
T235P20W	540	8.75	0.121	4.48	SEP-13-79	7	0.01	SPECIAL STUDY
T236P20W	566	11.2	0.0946	3.50	SEP-13-79	7	0.01	SPECIAL STUDY
T237P20W	560	10.3	0.103	3.81	SEP-13-79	7	0.01	SPECIAL STUDY
T238P20W	581	10.2	0.104	3.85	SEP-26-79	7	0.01	SPECIAL STUDY
T239P20W	541	10.8	0.0980	3.63	OCT-29-79	7	0.01	SPECIAL STUDY
T246P20Y	59	2.09	0.120	4.44	JAN-20-81	14	0.02	SPECIAL STUDY
T255P20E	830	54.0	0.0956	3.54	SEP-22-83	42	0.05	SPECIAL STUDY
T267P20+	1827	10.5	0.0957	3.54	APR-15-86	7	0.01	SPECIAL STUDY
T268P20+	1826	12.1	0.0956	3.54	APR-17-86	7	0.01	SPECIAL STUDY
T269P20+	1840	10.6	0.0948	3.51	MAY-27-86	224	0.23	SPECIAL STUDY
T270P20+	1846	11.7	0.0957	3.54	MAY-29-86	224	0.23	SPECIAL STUDY
T271P20+	1839	13.4	0.0956	3.54	JUN-10-86	28	0.03	SPECIAL STUDY
T272P20+	1841	14.1	0.0962	3.56	JUN-12-86	28	0.03	SPECIAL STUDY
T273P20+	1846	8.83	0.0943	3.49	JUN-10-86	56	0.06	SPECIAL STUDY
T274P20+	1848	10.1	0.0958	3.54	JUN-12-86	56	0.06	SPECIAL STUDY
T282P20	568	9.03	0.0961	3.56	MAR-18-86	224	0.26	SPECIAL STUDY
T283P20	570	11.7	0.0960	3.55	MAR-20-86	224	0.26	SPECIAL STUDY

B.19 ^{239}Pu, Test Studies (continued)

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T284P20	571	10.3	0.0959	3.55	MAR-25-86	455	0.50	SPECIAL STUDY
T285P20	573	11.2	0.0960	3.55	MAR-27-86	455	0.50	SPECIAL STUDY
T286P20	573	10.6	0.0967	3.58	MAR-25-86	112	0.14	SPECIAL STUDY
T287P20	575	10.3	0.0954	3.53	MAR-27-86	112	0.14	SPECIAL STUDY
T288P20	555	11.3	0.0972	3.60	APR-29-86	56	0.07	SPECIAL STUDY
T289P20	557	12.5	0.0964	3.57	MAY-01-86	56	0.07	SPECIAL STUDY
T290P20	562	14.0	0.0964	3.57	MAY-06-86	28	0.04	SPECIAL STUDY
T291P20	564	9.59	0.0965	3.57	MAY-08-86	28	0.03	SPECIAL STUDY
T293P20	566	11.1	0.0957	3.54	MAR-18-86	448	0.50	SPECIAL STUDY
T294P20	568	13.1	0.0957	3.54	MAR-20-86	448	0.50	SPECIAL STUDY
T295P20	556	13.8	0.0928	3.43	JUL-15-86	224	0.26	SPECIAL STUDY
T296P20	558	13.0	0.0924	3.42	JUL-17-86	224	0.25	SPECIAL STUDY
T297P20	563	11.0	0.0936	3.46	JUL-22-86	225	0.26	SPECIAL STUDY
T298P20	626	13.2	0.0901	3.33	SEP-23-86	56	0.07	SPECIAL STUDY
T299P20	554	12.4	0.0952	3.52	SEP-25-86	56	0.07	SPECIAL STUDY
T300P20	559	12.6	0.0952	3.52	SEP-30-86	56	0.07	SPECIAL STUDY
T301P20	608	12.6	0.0936	3.45	NOV-18-86	112	0.13	SPECIAL STUDY
T302P20	610	12.4	0.0952	3.52	NOV-20-86	112	0.14	SPECIAL STUDY
T303P20	560	12.3	0.0923	3.42	NOV-25-86	112	0.13	SPECIAL STUDY
T304P20	597	12.0	0.104	3.84	FEB-19-87	28	0.04	SPECIAL STUDY
T305P20	569	12.8	0.0959	3.55	FEB-24-87	28	0.04	SPECIAL STUDY
T306P20	571	10.7	0.0963	3.56	FEB-26-87	28	0.04	SPECIAL STUDY
T307P20	546	12.5	0.0878	3.25	MAY-05-87	7	0.01	SPECIAL STUDY
T308P20	548	13.1	0.0962	3.56	MAY-07-87	7	0.01	SPECIAL STUDY
T309P20+	1808	13.0	0.0947	3.50	MAY-13-86	448	0.44	SPECIAL STUDY
T310P20+	1816	13.1	0.0956	3.54	MAY-15-86	448	0.44	SPECIAL STUDY
T313P20Y	300	11.6	0.0890	3.29	APR-08-87	14	0.02	SPECIAL STUDY
T314P20Y	301	10.4	0.0890	3.29	APR-09-87	14	0.02	SPECIAL STUDY
T315P20Y	208	9.40	0.0942	3.49	AUG-13-87	14	0.02	SPECIAL STUDY
T316P20Y	209	10.9	0.0922	3.41	AUG-14-87	14	0.02	SPECIAL STUDY
T317P20Y	152	6.55	0.0991	3.67	MAY-14-87	14	0.02	SPECIAL STUDY
T318P20Y	150	7.18	0.104	3.85	JUN-16-87	14	0.02	SPECIAL STUDY
T319P20	580	13.5	0.0839	3.10	JUN-08-87	21	0.02	SPECIAL STUDY
T320P20	580	10.8	0.106	3.92	JUN-08-87	21	0.03	SPECIAL STUDY
T321P20	660	13.0	0.0970	3.59	SEP-29-87	14	0.02	SPECIAL STUDY
T322P20	661	12.1	0.0970	3.59	SEP-30-87	14	0.02	SPECIAL STUDY
T323P20	660	13.3	0.0980	3.63	SEP-29-87	63	0.08	SPECIAL STUDY
T324P20	661	13.4	0.0966	3.57	SEP-30-87	63	0.08	SPECIAL STUDY
T325P20	959	10.7	0.112	4.14	DEC-29-87	1	0.01	SPECIAL STUDY
T027P30	556	11.5	0.332	12.3	JUL-28-61	755	3.02	SPECIAL STUDY
T029P30	552	12.1	0.296	11.0	AUG-09-61	560	1.99	SPECIAL STUDY
T031P30	520	13.0	0.305	11.3	AUG-09-61	40	0.16	SPECIAL STUDY
T035P30	550	11.9	0.303	11.2	SEP-15-61	362	1.35	SPECIAL STUDY
T038P30	489	7.96	0.304	11.2	SEP-15-61	187	0.72	SPECIAL STUDY

B.19 ^{239}Pu, Test Studies (continued)

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
	INJECTION							
T050P30	102	5.30	0.296	11.0	JUL-05-66	2835	8.63	OSTEOSARCOMA
T058P30E	575	52.3	0.291	10.8	SEP-10-69	917	3.12	OSTEOSARCOMA
T059P30E	591	44.5	0.290	10.7	NOV-05-69	973	3.28	OSTEOSARCOMA
T060P30E	567	45.2	0.314	11.6	JAN-06-70	784	2.92	OSTEOSARCOMA
T077P30	3413	9.95	0.310	11.5	MAR-28-73	1623	5.03	OSTEOSARCOMA
T078P30	2480	8.21	0.320	11.8	MAR-28-73	1633	5.22	OSTEOSARCOMA
T240P30+	2231	6.06	0.282	10.4	JUL-29-80	511	1.48	SPECIAL STUDY
T241P30+	2161	14.2	0.160	5.92	JUL-29-80	518	0.85	SPECIAL STUDY
T242P30+	2208	9.85	0.231	8.55	JUL-29-80	425	1.46	SPECIAL STUDY, PANCREATITIS
T243P30+	2001	7.10	0.250	9.25	JUL-29-80	657	1.65	SPECIAL STUDY, PANCREATITIS
T247P30+	1877	9.85	0.323	12.0	MAR-03-81	280	0.96	SPECIAL STUDY
T251P30+	1839	10.1	0.304	11.2	SEP-29-81	273	0.88	SPECIAL STUDY, PANCREATITIS
T256P30W	555	13.1	0.256	9.47	JAN-31-84	1753	1.69	OSTEOSARCOMA
T257P30W	555	9.98	0.336	12.4	JAN-31-84	2088	2.83	OSTEOSARCOMA
T311P30	950	14.2	0.300	11.1	NOV-25-86	7	0.03	SPECIAL STUDY
T312P30	950	12.7	0.299	11.1	NOV-25-86	49	0.19	SPECIAL STUDY
T052P40	437	11.3	0.949	35.1	JUL-07-67	14	0.17	SPECIAL STUDY
T053P40	445	10.6	0.785	29.0	JUN-03-69	14	0.14	SPECIAL STUDY
T065P40P	542	11.5	0.904	33.4	NOV-30-71	14	0.02	SPECIAL STUDY
T066P40P	542	10.6	0.913	33.8	NOV-30-71	1184	6.63	FIBROSARCOMA (SKELETON)
T067P40P	539	10.4	0.907	33.6	NOV-30-71	1148	6.30	OSTEOSARCOMA
T074P40	3694	7.73	0.937	34.7	MAR-28-73	705	7.41	UNDIFFERENTIATED MALIGNANCY (SOFT TISSUE)
T075P40	3478	8.47	0.897	33.2	MAR-28-73	1451	13.6	OSTEOSARCOMA
T076P40	3413	10.7	0.894	33.1	MAR-28-73	1357	12.8	OSTEOSARCOMA
T086P40E	525	46.0	0.993	37.4	FEB-27-75	901	9.87	OSTEOSARCOMA
T130P40P	609	9.66	0.788	29.2	NOV-18-76	60	0.10	SPECIAL STUDY
T131P40P	609	12.0	0.799	29.6	NOV-18-76	1097	1.10	THROMBOEMBOLISM
T132P40P	609	10.1	0.804	29.7	NOV-18-76	132	0.15	SPECIAL STUDY
T133P40P	609	9.95	0.800	29.6	NOV-18-76	1783	2.23	OSTEOSARCOMA
T134P40P	609	9.87	0.789	29.2	NOV-18-76	1660	2.91	ADAMANTINOMA, MALIGNANT
T135P40P	609	11.3	0.799	29.6	NOV-18-76	69	0.12	SPECIAL STUDY
T136P40P	603	10.2	0.794	29.4	NOV-18-76	3508	2.69	SPECIAL STUDY
T137P40P	609	11.4	0.792	29.3	NOV-18-76	257	0.69	SPECIAL STUDY
T138P40P	603	9.66	0.788	29.2	NOV-18-76	138	2.08	SPECIAL STUDY
T139P40P	609	12.2	0.798	29.5	NOV-18-76	417	1.32	SPECIAL STUDY
T140P40P	603	9.79	0.796	29.5	NOV-18-76	824	3.98	SPECIAL STUDY
T141P40P	602	10.3	0.790	29.2	NOV-18-76	40	0.05	SPECIAL STUDY
T142P40P	602	8.23	0.791	29.3	NOV-18-76	33	0.04	SPECIAL STUDY
T143P40P	603	10.2	0.798	29.5	NOV-18-76	1267	6.11	OSTEOSARCOMA
T144P40P	602	9.82	0.793	29.3	NOV-18-76	1283	5.87	OSTEOSARCOMA
T145P40P	603	10.0	0.791	29.3	NOV-18-76	117	0.31	SPECIAL STUDY
T146P40P	602	9.63	0.790	29.2	NOV-18-76	124	0.24	SPECIAL STUDY
T147P40P	597	11.0	0.804	29.7	NOV-18-76	1462	2.28	OSTEOSARCOMA
T148P40P	602	9.67	0.806	29.8	NOV-18-76	250	0.64	SPECIAL STUDY

B.19 ^{239}Pu, Test Studies (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T149P40P	597	9.86	0.790	29.2	NOV-18-76	3533	2.04	SPECIAL STUDY
T150P40P	597	9.84	0.792	29.3	NOV-18-76	424	1.34	SPECIAL STUDY
T151P40P	597	11.4	0.792	29.3	NOV-18-76	831	3.60	SPECIAL STUDY
T152P40P	597	8.90	0.796	29.5	NOV-18-76	1568	9.19	OSTEOSARCOMA
T157P40P	609	11.2	0.790	29.2	NOV-18-76	1594	7.08	OSTEOSARCOMA
T249P40	1413	8.38	0.924	34.2	MAY-13-81	8	0.08	SPECIAL STUDY
T250P40	1019	10.2	0.926	34.3	MAY-13-81	35	0.36	SPECIAL STUDY
T000P50	646	11.4	3.05	113.	JUN-24-52	1	0.04	SPECIAL STUDY
T001P50	1581	12.7	3.04	112.	OCT-13-52	29	1.06	SPECIAL STUDY
T002P50	914	11.9	6.85	253.	SEP-15-52	44	3.94	SPECIAL STUDY
T003P50	942	9.65	3.22	119.	OCT-13-52	610	24.8	SPECIAL STUDY
T004P50	1015	8.78	3.02	112.	OCT-13-52	365	11.6	SPECIAL STUDY
T005P50	474	10.4	2.69	99.5	DEC-14-54	400	13.7	SPECIAL STUDY
T006P50	527	6.16	2.73	101.	DEC-14-54	406	14.1	SPECIAL STUDY
T007P50	475	7.40	2.68	99.2	DEC-14-54	777	26.1	SPECIAL STUDY
T008P50	527	8.32	2.67	98.8	DEC-14-54	863	28.70	SPECIAL STUDY
T009P50	551	10.3	2.80	104.	NOV-22-55	15	0.55	SPECIAL STUDY
T010P50	534	11.9	2.74	101.	NOV-23-55	15	0.54	SPECIAL STUDY
T011P50	516	12.1	2.76	102.	NOV-22-55	28	1.01	SPECIAL STUDY
T012P50	487	9.23	2.74	101.	NOV-23-55	28	1.00	SPECIAL STUDY
T013P50	587	8.27	3.16	117.	APR-24-56	3	0.12	SPECIAL STUDY
T014P50	587	9.38	2.43	89.9	APR-24-56	7	0.22	SPECIAL STUDY
T015P50	737	8.32	2.79	103.	OCT-15-56	1	0.04	SPECIAL STUDY
T016P50	673	10.7	2.85	105.	OCT-10-56	92	3.41	SPECIAL STUDY
T017P50	739	11.1	3.01	111.	FEB-12-57	210	8.16	SPECIAL STUDY
T018P50	739	8.16	2.83	105.	FEB-12-57	217	7.93	SPECIAL STUDY
T019P50	688	8.86	2.91	108.	DEC-15-60	1400	49.8	OSTEOSARCOMA, BLOOD DYSCRASIA, DEGENERATION (LIVER)
T020P50	688	13.0	2.68	99.2	DEC-15-60	474	16.1	DEGENERATION (LIVER), ASCITES, THROMBOCYTOPENIA
T021P50	688	10.3	2.72	101.	DEC-15-60	939	31.7	NEPHRITIS, DEGENERATION (LIVER)
T041P50	543	8.50	3.01	111.	NOV-30-64	1227	45.4	PURPURA HEMORRHAGICA, DEGENERATION (LIVER)
T042P50	510	11.4	2.40	88.8	FEB-10-65	13	0.41	SPECIAL STUDY
T043P50H	600	14.0	2.86	106.	JUL-15-65	40	1.52	SPECIAL STUDY
T044P50H	516	12.0	2.72	101.	SEP-21-65	35	1.25	SPECIAL STUDY
T046P50	420	11.9	3.01	111.	OCT-28-65	732	27.6	DEGENERATION (LIVER)
T047P50	803	12.4	3.02	112.	NOV-30-65	69	2 72	SPECIAL STUDY
T048P50	554	8.50	2.61	96.6	MAR-11-66	1327	42.4	UNDIFFERENTIATED SARCOMA (SKELETON)
T051P50	103	4.80	2.73	101.	JUL-06-66	1055	20.8	OSTEOSARCOMA
T053P50	1517	13.9	2.82	104.	MAR-11-69	1559	39.2	DEGENERATION (LIVER)
T054P50	906	11.3	2.77	102.	MAR-11-69	404	14.3	SPECIAL STUDY
T063P50	581	9.13	2.77	102.	DEC-14-70	490	17.2	SPECIAL STUDY
T087P50	3008	10.1	2.93	108.	FEB-24-75	182	5.74	SPECIAL STUDY
T088P50	2194	9.80	3.01	111.	FEB-24-75	184	5.96	SPECIAL STUDY
T153P50	567	12.0	2.55	94.3	NOV-16-76	22	0.73	SPECIAL STUDY
T222P50Y	91	3.08	3.27	121.	JAN-15-79	7	0.33	SPECIAL STUDY

B.19 ^{239}Pu, Test Studies (continued)

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
	INJECTION							
T223P50Y	91	2.18	2.77	102.	JAN-15-79	7	0.28	SPECIAL STUDY
T224P50Y	91	2.55	3.23	120.	JAN-15-79	14	0.65	SPECIAL STUDY
T225P50Y	91	2.08	2.72	101.	JAN-15-79	14	0.54	SPECIAL STUDY
T056P55	501	11.2	3.73	138.	JUL-29-69	7	0.34	SPECIAL STUDY
T116P55	533	8.72	4.32	160.	JAN-13-76	2	0.11	SPECIAL STUDY
T198P55	1560	7.92	4.57	169.	APR-10-78	2	0.10	SPECIAL STUDY
T199P55	1377	10.7	4.54	168.	APR-10-78	2	0.10	SPECIAL STUDY
T200P55	657	10.9	4.34	161.	JUN-13-77	2	0.11	SPECIAL STUDY

FOR THE CALCULATION OF RADIATION DOSE FOR DOGS THAT HAD RECEIVED PARTICULATE PLUTONIUM, MEASURED SKELETAL WEIGHTS WERE USED. THE FOLLOWING SKELETAL PU-RETENTIONS (R) WERE APPLIED:

A. DOGS THAT RECEIVED NO FURTHER TREATMENT R = 60(1 - 0.914 exp0.00098t)exp-0.000237t.
B. DOGS THAT RECEIVED 30 MMOLES CaDTPA/KG ONCE WEEKLY R = 6.7% CONSTANT AVERAGE RETENTION.
C. DOGS THAT RECEIVED 309 UMOLES ZnDTPA/KG DAILY R = 2.8% CONSTANT AVERAGE RETENTION.

T117P20Y ... T122P20Y AND T123P20 WERE GIVEN TRACER PU-237 IN THE SAME SOLUTION CONTAINING THEIR PU-239.

DOGS IN THE SEQUENCE T213P20W ... T221P17W AND T226P17W ... T239P20W WERE GIVEN A MIXTURE OF PU-239, PU-237 AND AM-241.

T043P50H WAS ALSO GIVEN 37.4 KBQ/KG (1.01 UCI/KG) PU-239 ONE DAY PRIOR TO SACRIFICE.

T044P50H WAS GIVEN 30.8 KBQ/KG (0.833 UCI/KG) PU-239 AND 339 KBQ/KG (9.17 UCI/KG) FE-59 ONE DAY PRIOR TO SACRIFICE.

B.20 ^{224}Ra (Quickradium) Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T019Q10	514	11.8	0.0475	1.76	FEB-01-68	4675	0.81	INANITION, DEGENERATION (KIDNEY)
T020Q10	514	10.4	0.0472	1.75	FEB-01-68	4717	0.81	ADENOMA (CHROMOPHOBE)
T021Q10	502	9.08	0.0447	1.65	FEB-01-68	4211	0.70	THROMBOEMBOLISM
T016Q20	514	9.36	0.310	11.5	FEB-01-68	3757	4.74	OSTEOSARCOMA
T017Q20	514	10.2	0.311	11.5	FEB-01-68	4893	5.46	OSTEOSARCOMA, THROMBOEMBOLISM
T018Q20	502	9.68	0.306	11.3	FEB-01-68	4961	5.40	SALIVARY GLAND TUMOR
T001Q30J	460	9.55	0.875	32.4	MAR-26-63	4/24	0.01	SPECIAL STUDY
T011Q30	495	9.10	0.885	32.7	DEC-04-63	3668	0.32	AORTIC BODY TUMOR
T012Q30	495	13.5	0.889	32.9	DEC-04-63	4087	0.32	THROMBOEMBOLISM
T013Q30	495	11.3	0.912	33.7	DEC-04-63	4605	0.33	CIRCULATORY FAILURE
T014Q30	438	10.3	0.870	32.2	DEC-04-63	4785	0.31	NEPHRITIS
T002Q40	466	12.0	2.91	108.	MAR-27-63	2317	6.71	OSTEOSARCOMA
T003Q40	466	13.1	2.91	108.	MAR-27-63	2708	7.31	HEMANGIOSARCOMA (SKELETON)
T009Q40	503	9.80	2.57	95.1	DEC-04-63	1451	0.88	STRANGULATION OF VOMITUS, STATUS EPILEPTICUS
T010Q40	503	10.3	2.57	95.1	DEC-04-63	262	0.80	STATUS EPILEPTICUS
T015Q40	514	12.7	2.73	101.	FEB-01-68	1692	25.8	OSTEOSARCOMA
T004Q50	479	9.55	9.71	359.	APR-24-63	1462	36.0	OSTEOSARCOMA, EPIDERMOID CARCINOMA (FRONTAL SINUS)
T005Q50	454	9.67	9.59	355.	APR-24-63	1638	38.2	OSTEOSARCOMA
T007Q50	465	11.8	8.56	317.	NOV-06-63	2053	3.61	OSTEOSARCOMA
T008Q50	475	9.77	8.62	319.	NOV-06-63	16	2.51	PURPURA HEMORRHAGICA
T022Q50	643	8.39	10.1	374.	DEC-13-77	3/24	0.04	SPECIAL STUDY
T023Q50	619	10.9	8.37	310.	JAN-03-78	1/24	0.01	SPECIAL STUDY
T024Q50	649	9.14	10.1	374.	DEC-19-77	1	0.49	SPECIAL STUDY
T025Q50	638	8.78	10.1	374.	JAN-10-78	8/24	0.14	SPECIAL STUDY
T026Q50	685	8.81	9.93	369.	JAN-24-78	7	2.29	SPECIAL STUDY
T027Q50	642	10.6	10.1	374.	JAN-14-78	3	1.37	SPECIAL STUDY
T028Q50	577	10.9	8.43	312.	DEC-04-79	1	0.41	SPECIAL STUDY
T029Q50	593	13.0	7.33	271.	APR-21-81	1	0.36	SPECIAL STUDY
T030Q50	606	12.2	9.75	361.	MAY-12-81	1	0.48	SPECIAL STUDY
T031Q50	775	10.5	10.6	392.	DEC-15-82	1	0.52	SPECIAL STUDY, PANCREATITIS
T006Q60	455	8.29	21.4	792.	OCT-17-63	13	6.47	PURPURA HEMORRHAGICA

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T001Q30J ALSO RECEIVED 666 KBQ (18.0 UCI) SR-85.

SKELETAL DOSES FOR T022Q50 TO T031Q50 ARE FROM RA-224 (AND DAUGHTERS). CONTAMINATION OF THE INJECTION SOLUTION WITH OTHER EMITTERS WAS NEGLIGIBLE. DOSIMETRIC DETAILS ARE TO BE FOUND IN COO-199-253, PP. 263-276, MARCH 1978.

FOR THE OTHER RA-224 TEST DOGS, THE SKELETAL DOSES ARE FROM RA-224 (AND DAUGHTERS) PLUS CONTAMINATION FROM PB-210 AND TH-228. IN SOME CASES THE PB-210 AND TH-228 CONTAMINATION WAS APPRECIABLE. PLEASE SEE THE ARTICLE, "RA-224 TOXICITY FROM A PILOT STUDY IN BEAGLES" IN COO-119-252, MARCH 1977, PP. 272-287, PARTICULARLY SEE P. 278. (NOTE THAT THE SKELETAL DOSES LISTED ON PAGE 278 OF THE REFERENCE CITED WERE CALCULATED FOR BEAGLES WITH 75 G SKELETON/KG BODY WEIGHT RATHER THAN 100 G/KG BODY WEIGHT AS USED HEREIN).

B.21 ^{226}Ra, Test Studies

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTION: INJECTED (UCI/KG)	INJECTION: INJECTED (KBQ/KG)	INJECTION: DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T039R00								REASSIGNED, SEE M012M00
T075R00	488	9.38			MAY-13-75	134		SPECIAL STUDY
T078R00	503	9.77			MAY-28-75	55		SPECIAL STUDY
T080R00	500	12.1			MAY-28-75	208		SPECIAL STUDY
T083R00	495	8.06			MAY-28-75	26		SPECIAL STUDY
T087R00	488	12.2			JUN-25-75	15		SPECIAL STUDY
T090R00	502	9.63			JUL-09-75	7		SPECIAL STUDY
T123R00E	540				JAN-07-74	3174		BLOAT
T124R00E	539				JUL-10-79	2772		SPECIAL STUDY
T155R00E	557	66.5			AUG-03-82	1010		LYMPHOSARCOMA
T156R00E	557	58.0			AUG-03-82	1025		HYDROCEPHALUS, CNS SYNDROME
T157R00E	557				DEC-23-82	1505		SPECIAL STUDY
T104R05E	519	47.9	0.0191	0.707	DEC-27-77	3314	0.85	SPECIAL STUDY, ADENOCARCINOMA, LUNG
T118R05E	565	46.9	0.0198	0.733	AUG-19-80	197	0.11	UNDIFFERENTIATED CARCINOMA (NOSE)
T119R05E	565	51.8	0.0196	0.725	AUG-19-80	3262	0.74	DEAD (NO CAUSE REC'D)
T133R05E	544	44.2	0.0192	0.710	DEC-01-81	2495		BATTELLE LABS
T134R05E	544	51.0	0.0191	0.707	DEC-01-81	2495		BATTELLE LABS
T040R10	899	13.0	0.0483	1.79	APR-03-62	7	0.01	SPECIAL STUDY
T041R10	899	12.7	0.0487	1.80	APR-03-62	63	0.04	SPECIAL STUDY
T105R10E	519	49.5	0.0558	2.06	DEC-27-77	1686	1.72	NEPHRITIS, PNEUMONIA
T115R10E	524	41.1	0.0605	2.24	JUL-29-80	2575	1.68	SPECIAL STUDY
T117R10E	544	40.3	0.0617	2.28	JUL-29-80	1416	1.23	ARTHRITIS
T120R10E	527	49.8	0.0618	2.29	SEP-16-80	2770	2.15	DEAD (NO CAUSE REC'D)
T121R10E	527	49.0	0.0614	2.27	SEP-16-80	3411	2.30	DEAD (NO CAUSE REC'D)
T042R17	967	14.0	0.146	5.40	APR-04-62	7	0.02	SPECIAL STUDY
T043R17	963	13.2	0.145	5.37	APR-04-62	64	0.13	SPECIAL STUDY
T073R20	487	8.68	0.350	13.0	MAY-06-75	380	1.92	SPECIAL STUDY
T074R20	438	12.0	0.314	11.6	MAY-13-75	28	0.17	SPECIAL STUDY
T076R20	488	11.6	0.318	11.8	MAY-13-75	56	0.34	SPECIAL STUDY
T077R20	489	12.3	0.313	11.6	MAY-14-75	7	0.04	SPECIAL STUDY
T079R20	503	9.23	0.357	13.2	MAY-28-75	127	1.15	SPECIAL STUDY
T081R20	495	11.1	0.365	13.5	MAY-28-75	205	2.16	SPECIAL STUDY
T082R20	495	10.3	0.359	13.3	MAY-28-75	28	0.19	SPECIAL STUDY
T084R20	512	11.0	0.314	11.6	JUN-06-75	132	1.02	SPECIAL STUDY
T085R20	490	9.24	0.265	9.81	JUN-10-75	210	1.49	SPECIAL STUDY
T086R20	487	13.8	0.313	11.6	JUN-24-75	15	0.09	SPECIAL STUDY
T088R20	490	11.7	0.328	12.1	JUL-01-75	365	1.75	SPECIAL STUDY
T089R20	491	12.2	0.329	12.2	JUL-02-75	15	0.09	SPECIAL STUDY
T091R20	513	10.3	0.253	9.36	JUN-10-75	56	0.40	SPECIAL STUDY
T092R20	459	11.6	0.327	12.1	AUG-05-75	7	0.05	SPECIAL STUDY
T099R20E	564	55.4	0.335	12.4	NOV-03-77	1602	6.76	OSTEOSARCOMA
T100R20E	491	48.6	0.341	12.6	NOV-22-77	1727	7.94	OSTEOSARCOMA
T102R20E	501	47.3	0.342	12.7	DEC-09-77	1587	9.73	OSTEOSARCOMA

B.21 ^{226}Ra, Test Studies (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T158R20Y	300	12.5	0.463	17.1	JUN-12-87	14	0.16	SPECIAL STUDY
T159R20Y	300	9.40	0.488	18.1	OCT-09-87	14	0.17	SPECIAL STUDY
T160R20Y	210	8.92	0.484	17.9	JUL-08-87	14	0.16	SPECIAL STUDY
T161R20Y	209	11.0	0.482	17.8	JUL-09-87	14	0.16	SPECIAL STUDY
T162R20Y	150	8.05	0.498	18.4	MAY-11-87	15	0.17	SPECIAL STUDY
T163R20Y	150	7.20	0.483	17.9	MAY-12-87	15	0.16	SPECIAL STUDY
T028R30H	371	11.7	1.11	41.1	NOV-24-58	387	3.67	SPECIAL STUDY
T032R30	471	11.4	1.13	41.8	MAR-03-59	2249	20.3	OSTEOSARCOMA
T033R30	471	10.6	1.15	42.6	MAR-03-59	1822	20.6	OSTEOSARCOMA, NEPHRITIS
T034R30	470	15.7	1.12	41.4	MAR-03-59	1737	17.4	OSTEOSARCOMA
T035R30J	470	9.44	0.951	35.2	MAY-05-59	8	0.14	SPECIAL STUDY
T044R30	938	11.1	0.937	34.7	APR-04-62	68	0.82	SPECIAL STUDY
T045R30	940	13.6	0.941	34.8	APR-06-62	7	0.12	SPECIAL STUDY
T046R30	810	12.5	0.928	34.3	APR-05-62	69	1.14	SPECIAL STUDY
T063R30	559	8.72	0.899	33.3	JAN-29-64	36	0.56	SPECIAL STUDY
T064R30	551	8.42	0.919	34.0	JAN-29-64	63	0.85	SPECIAL STUDY
T065R30	551	11.6	0.922	34.1	JAN-29-64	70	1.11	SPECIAL STUDY
T066R30	549	10.1	0.904	33.4	JAN-29-64	132	1.65	SPECIAL STUDY
T067R30	549	12.7	0.898	33.2	JAN-29-64	134	1.92	SPECIAL STUDY
T068R30	549	12.1	0.917	33.9	JAN-29-64	1667	12.1	OSTEOSARCOMA
T069R30	498	8.84	0.919	34.0	JAN-29-64	622	6.75	SPECIAL STUDY
T070R30	498	14.2	0.922	34.1	JAN-29-64	1996	23.2	OSTEOSARCOMA
T093R30	576	7.75	0.969	35.9	JAN-27-76	3	0.06	SPECIAL STUDY
T094R30	571	9.88	0.930	34.4	JAN-23-76	11	0.24	SPECIAL STUDY
T095R30	584	10.2	1.03	38.1	FEB-17-76	14	0.36	SPECIAL STUDY
T096R30	584	7.94	0.990	36.6	FEB-17-76	7	0.13	SPECIAL STUDY
T097R30	583	10.8	0.972	36.0	FEB-26-76	4	0.09	SPECIAL STUDY
T098R30	549	9.51	0.966	35.7	FEB-20-76	18	0.34	SPECIAL STUDY
T101R30E	491	45.6	1.05	38.8	NOV-22-77	523	11.9	STATUS EPILEPTICUS
T103R30E	501	45.4	1.10	40.7	DEC-09-77	955	20.7	OSTEOSARCOMA
T107R30Y	101	4.41	1.01	37.4	FEB-21-80	119	1.94	SPECIAL STUDY
T108R30Y	101	3.97	1.06	39.2	FEB-21-80	238	3.64	SPECIAL STUDY
T109R30Y	101	3.73	1.05	38.8	FEB-21-80	364	5.88	SPECIAL STUDY
T110R30E	1297	58.8	1.04	38.5	FEB-13-80	15	0.37	SPECIAL STUDY
T111R30Y	92	4.67	1.06	39.2	MAR-13-80	21	0.51	SPECIAL STUDY
T112R30Y	92	3.52	1.05	38.8	MAR-13-80	49	1.08	SPECIAL STUDY
T113R30Y	92	3.17	1.09	40.3	APR-08-80	7	0.18	SPECIAL STUDY
T114R30Y	92	3.22	1.07	39.6	APR-08-80	14	0.34	SPECIAL STUDY
T135R30+	1850	10.8	1.14	42.2	AUG-01-84	7	0.11	SPECIAL STUDY
T136R30+	2276	11.2	1.14	42.2	AUG-01-84	14	0.25	SPECIAL STUDY
T137R30+	2194	11.8	1.14	42.2	AUG-22-84	34	0.57	SPECIAL STUDY

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T035R30J ALSO RECEIVED 3660 KBQ (99.0 UCI) SR-85.

B.21 ^{226}Ra, Test Studies (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T138R30+	1822	11.7	1.14	42.2	AUG-22-84	64	0.90	SPECIAL STUDY
T139R30+	2276	11.5	1.14	42.2	AUG-01-84	133	1.69	SPECIAL STUDY
T140R30+	1822	13.2	1.14	42.2	AUG-22-84	239	2.72	SPECIAL STUDY
T141R30+	2151	9.97	1.14	42.2	AUG-01-84	370	4.23	SPECIAL STUDY
T144R30	613	12.1	0.911	33.7	DEC-10-84	7	0.10	SPECIAL STUDY
T145R30	620	12.0	0.918	34.0	DEC-17-84	239	2.82	SPECIAL STUDY
T146R30	620	13.0	0.907	33.6	DEC-17-84	241	3.43	SPECIAL STUDY
T147R30	652	13.[illegible]	0.896	33.2	JAN-02-85	398	5.07	SPECIAL STUDY
T148R30	652	13.7	0.919	34.0	JAN-02-85	14	0.20	SPECIAL STUDY
T149R30	644	14.5	0.909	33.6	JAN-09-85	29	0.50	SPECIAL STUDY
T150R30	644	13.3	0.908	33.6	JAN-09-85	34	0.54	SPECIAL STUDY
T151R30	635	12.3	0.909	33.6	JAN-16-85	75	0.87	SPECIAL STUDY
T152R30	635	13.2	0.903	33.4	JAN-16-85	78	1.10	SPECIAL STUDY
T153R30	626	12.8	1.10	40.7	APR-02-85	118	1.79	SPECIAL STUDY
T154R30	609	10.2	1.10	40.7	APR-02-85	122	1.74	SPECIAL STUDY
T125R35N	2	0.32	1.53	56.6	JUL-06-81	2	0.02	SPECIAL STUDY
T126R35N	2	0.32	1.58	58.5	JUL-06-81	4	0.05	SPECIAL STUDY
T127R35N	2	0.30	1.66	61.4	JUL-06-81	4	0.05	SPECIAL STUDY
T128R35N	2	0.31	1.60	59.2	JUL-06-81	1	0.01	SPECIAL STUDY
T129R35N	2	0.31	1.60	59.2	JUL-06-81	14	0.17	SPECIAL STUDY
T130R35N	4	0.36	1.34	49.6	JUL-27-81	4	0.04	SPECIAL STUDY
T131R35N	4	0.40	1.20	44.4	JUL-27-81	7	0.07	SPECIAL STUDY
T132R35N	4	0.35	1.37	50.7	JUL-27-81	14	0.15	SPECIAL STUDY
T014R40	675	8.12	3.17	117.	JUL-12-56	72	3.90	SPECIAL STUDY
T015R40	672	9.03	3.11	115.	JUL-11-56	2127	53.9	OSTEOSARCOMA
T023R40H	384	9.50	4.05	150.	NOV-25-58	1471	54.1	OSTEOSARCOMA
T024R40H	383	11.9	3.24	120.	NOV-24-58	1505	44.1	OSTEOSARCOMA
T025R40H	378	11.3	3.42	127.	NOV-24-58	1309	41.6	OSTEOSARCOMA
T026R40H	378	11.0	3.48	129.	NOV-24-58	1780	54.0	OSTEOSARCOMA
T027R40H	371	11.5	3.34	124.	NOV-24-58	1414	43.3	OSTEOSARCOMA
T036R40	695	10.2	2.99	111.	DEC-22-60	1154	39.9	OSTEOSARCOMA
T037R40	695	9.53	3.00	111.	DEC-22-60	1627	36.8	OSTEOSARCOMA
T038R40	695	10.1	3.02	112.	DEC-22-60	1503	40.8	OSTEOSARCOMA
T057R40	500	12.1	2.72	101.	AUG-15-63	14	0.59	SPECIAL STUDY
T058R40	495	11.7	2.41	89.2	AUG-15-63	61	3.11	SPECIAL STUDY
T059R40	495	9.64	2.57	95.1	AUG-15-63	63	3.01	SPECIAL STUDY
T060R40	489	12.1	2.33	86.2	AUG-15-63	117	4.67	SPECIAL STUDY
T061R40	489	9.48	2.70	99.9	AUG-15-63	371	17.3	SPECIAL STUDY
T062R40	489	8.63	2.68	99.2	AUG-15-63	460	17.8	SPECIAL STUDY
T001R50	996	11.1	10.3	381.	DEC-01-52	1074	95.2	OSTEOSARCOMA
T002R50	919	8.40	4.39	162.	JAN-12-53	1368	47.6	OSTEOSARCOMA
T003R50	1467	8.29	4.76	176.	JAN-12-53	428	13.2	SPECIAL STUDY
T004R50	459	10.0	10.6	392.	JUL-06-53	1	0.14	SPECIAL STUDY
T005R50	126	6.14	11.7	433.	OCT-06-53	1	0.15	SPECIAL STUDY

B.21 ^{226}Ra, Test Studies (continued)

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T006R50	126	6.14	11.4	422.	OCT-06-53	1	0.15	SPECIAL STUDY
T007R50	126	6.14	11.8	437.	OCT-06-53	1	0.15	SPECIAL STUDY
T008R50	320	5.52	1.92	71.	MAY-10-55	58	4.58	SPECIAL STUDY
T009R50	2274	10.4	1.94	71.8	MAY-10-55	58	5.48	SPECIAL STUDY
T010R50	44	1.02	1.98	73.3	MAY-11-55	49	2.79	SPECIAL STUDY
T011R50	44	1.58	1.91	70.7	MAY-11-55	49	3.44	SPECIAL STUDY
T012R50	397	12.3	9.72	360.	MAY-09-56	225	28.3	SPECIAL STUDY
T013R50	397	7.59	9.76	361.	MAY-09-56	188	24.3	SPECIAL STUDY
T016R50	604	12.4	9.68	358.	JUL-11-57	12	1.64	SPECIAL STUDY
T017R50H	384	12.2	9.87	365.	OCT-29-58	1140	107.	OSTEOSARCOMA, ULCER (MOUTH)
T018R50H	384	11.1	10.8	400.	OCT-29-58	1226	125.	OSTEOSARCOMA, ULCER (MOUTH)
T019R50H	384	11.3	10.7	396.	OCT-29-58	1219	123.	OSTEOSARCOMA, ULCER (MOUTH)
T020R50H	384	11.4	10.6	392.	OCT-29-58	1340	132.	CHONDROSARCOMA
T021R50H	382	11.8	10.1	374.	OCT-29-58	386	35.9	NEPHRITIS
T022R50H	382	11.9	10.1	374.	OCT-29-58	587	58.9	CRIPPLING FRACTURE
T029R50	474	13.5	10.4	385.	MAR-03-59	216	36.5	NEPHRITIS
T030R50	474	11.5	10.4	385.	MAR-03-59	178	30.5	NEPHRITIS
T031R50	471	10.5	10.4	385.	MAR-03-59	303	50.4	NEPHRITIS
T049R50	485	10.6	7.54	279.	MAY-02-63	5	0.85	SPECIAL STUDY
T050R50	485	13.7	7.46	276.	MAY-02-63	15	2.62	SPECIAL STUDY
T051R50	418	13.3	8.48	314.	MAY-08-63	92	18.1	SPECIAL STUDY
T052R50	418	10.7	8.57	317.	MAY-08-63	15	2.52	SPECIAL STUDY
T053R50	418	12.0	8.50	315.	MAY-08-63	33	6.18	SPECIAL STUDY
T054R50	416	11.4	8.76	324.	MAY-22-63	5	0.71	SPECIAL STUDY
T055R50	416	11.6	8.61	319.	MAY-22-63	33	5.50	SPECIAL STUDY
T056R50	416	11.6	8.61	319.	MAY-22-63	90	15.1	SPECIAL STUDY
T071R50	4025	13.8	9.23	342.	JAN-28-69	42	6.98	MELANOMA (MOUTH)
T072R50	4776	9.45	12.4	459.	AUG-17-72	54	12.6	SPECIAL STUDY
T115R50	572	11.4	8.74	323.	JUN-23-80	1	0.14	SPECIAL STUDY
T142R50+	2488	10.4	12.2	452.	JUL-12-84	96	14.3	SPECIAL STUDY
T143R50+	2478	10.8	12.2	450.	JUL-12-84	862	77.7	SPECIAL STUDY
T047R60	99	5.27	29.4	1090.	JUN-11-62	4	2.87	SPECIAL STUDY
T048R60	2843	11.2	25.1	929.	DEC-28-62	49	17.6	LEUKOPENIA, PNEUMONIA

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THE MULTIPLE INJECTION DOGS WERE MALE BEAGLES BORN IN DAVIS, CALIFORNIA, BUT INJECTED IN OUR LABORATORY. EACH WAS INJECTED SIX TIMES OVER A 280 DAY PERIOD WITH 56 DAYS BETWEEN EACH INJECTION. EACH RA-226 INJECTION WAS 740 KBQ (20.0 UCI) FOR THE DOGS T017R50H ... T022R50H; 237 KBQ (6.41 UCI) FOR T023R40H ... T027R40H; AND 96.6 KBQ (2.61 UCI) FOR T028R30H. TABULATED FOR EACH DOG IS AGE AT FIRST INJECTION, AVERAGE WEIGHT DURING THE INJECTION PERIOD, TOTAL UCI/AVERAGE WEIGHT, THE DATE OF FIRST INJECTION, THE TIME FROM FIRST INJECTION TO DEATH, AND THE SUM OF THE SKELETAL DOSES COMPUTED FROM EACH INJECTION TO DEATH.

B.22 ^{228}Ra (Mesothorium), Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T001H45	528	9.13	4.23	157	SEP-08-54	314	15.2	CANINE DISTEMPER
T002H45	463	8.93	4.27	158	SEP-08-54	755	50.1	SPECIAL STUDY
T003H50	579	9.15	10.6	392	MAR-13-56	700	157.	ULCER (MOUTH), ANEMIA, CRIPPLING FRACTURE

KBQ TH-228 / KBQ RA-228) INJECTED = 0.03.

B.23 ^{90}Sr, Test Studies.

DOG NUMBER	AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
	INJECTION							
T001S00	151	7.71			MAR-05-54	112		SPECIAL STUDY
T008S00	243	7.00			NOV-04-54	0		SPECIAL STUDY
T008S20H	97	3.69	2.74	101.	SEP-27-55	66	0.14	SPECIAL STUDY
T009S20H	97	2.79	3.62	134.	SEP-27-55	66	0.19	SPECIAL STUDY
T010S20H	97	3.11	3.25	120.	SEP-27-55	132	0.45	SPECIAL STUDY
T011S20H	97	3.85	2.62	96.9	SEP-27-55	132	0.36	SPECIAL STUDY
T016S20	604	9.71	3.27	121.	NOV-08-61	9	0.04	SPECIAL STUDY
T021S25J	362	7.20	8.30	307.	OCT-02-63	13	0.94	SPECIAL STUDY
T012S30	593	10.6	10.5	389.	SEP-11-57	5	0.08	BREMSSTRAHLUNG PHANTOM
T013S40	324	10.5	19.1	707.	JUL-08-60	8	0.30	BREMSSTRAHLUNG PHANTOM, SAM MCGEE
T020S40J	440	8.54	28.9	1070.	OCT-02-63	13	0.52	SPECIAL STUDY
T002S50	149	6.85	148.	5480.	MAR-05-54	18	4.14	SPECIAL STUDY
T003S50	144	6.19	148.	5480.	MAR-05-54	28	6.34	SPECIAL STUDY
T004S50	151	7.05	148.	5480.	MAR-05-54	41	9.10	SPECIAL STUDY
T005S50	144	5.25	148.	5480.	MAR-05-54	116	23.3	SPECIAL STUDY
T006S50	155	7.01	87.0	3220.	MAR-16-54	1/24	0.01	SPECIAL STUDY
T007S50	155	6.74	87.0	3220.	MAR-16-54	2	0.28	SPECIAL STUDY
T014S50	542	10.0	96.1	3560.	NOV-07-61	9	1.07	SPECIAL STUDY
T015S50	595	9.43	98.4	3640.	NOV-07-61	30	3.33	SPECIAL STUDY
T022S50	545	9.01	99.0	3660.	APR-01-69	1525	86.6	HEMANGIOSARCOMA (SKELETON)
T023S50	545	11.6	100.	3700.	APR-01-69	1379	105.	OSTEOSARCOMA
T017S60	670	7.18	295.	10915.	JAN-19-62	14	4.66	LEUKOPENIA, THROMBOCYTOPENIA, PURPURA HEMORRHAGICA
T018S60	670	5.94	302.	11174.	JAN-19-62	1369	166.	HEMANGIOSARCOMA (SKELETON)
T019S60	670	5.43	284.	10508.	JAN-19-62	24	4.93	LEUKOPENIA, THROMBOCYTOPENIA

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T008S20 ... T011S20H WERE GIVEN 10 INJECTIONS, 37 KBQ (1 UCI SR-90) EACH AT WEEKLY INTERVALS. AGE IS AT FIRST INJECTION, WEIGHT IS AVERAGE DURING THE INJECTION PERIOD, KBQ/KG (UCI/KG) IS TOTAL SR-90/AVERAGE WEIGHT, DATE IS AT FIRST INJECTION. DAYS ARE FROM FIRST INJECTION TO DEATH, AND DOSE IS COMPUTED, FROM MID-INJECTION TO DEATH.

T020S40J RECEIVED 18.5 KBQ (0.5 UCI) SR-85 IN ADDITION TO THE 9130 KBQ (246.8 UCI) SR-90.
T021S25J RECEIVED 18.5 KBQ (0.5 UCI) SR-85 AND 22200 KBQ (600 UCI) SR-89 IN ADDITION TO THE 2210 KBQ (59.8 UCI) SR-90.

B.24 ^{228}Th, Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T001M45	528	9.13	4.23	157	SEP-08-54	314	15.2	CANINE DISTEMPER
T002M45	463	8.93	4.27	158	SEP-08-54	755	50.1	SPECIAL STUDY
T003M50	579	9.15	10.6	392	MAR-13-56	700	157.	ULCER (MOUTH), ANEMIA, CRIPPLING FRACTURE

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KBQ TH-228 / KBQ RA-228) INJECTED = 0.03.

B.25 ^{232}U and/or ^{233}U, Test Studies

DOG NUMBER	INJECTION: AGE (DAYS)	INJECTION: WEIGHT (KG)	INJECTION: INJECTED (UCI/KG)	INJECTION: INJECTED (KBQ/KG)	INJECTION: DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T023U30	571	10.0	0.284	10.5	DEC-09-80	363		SPECIAL STUDY
T024U30	571	8.52	0.283	10.5	DEC-09-80	365		SPECIAL STUDY
T025U30	566	10.4	0.291	10.8	DEC-09-80	168		SPECIAL STUDY
T026U30	560	11.1	0.284	10.5	DEC-09-80	169		SPECIAL STUDY
T027U30	537	8.83	0.266	9.8	DEC-09-80	93		SPECIAL STUDY
T028U30	567	10.4	0.285	10.5	DEC-09-80	91		SPECIAL STUDY
T029U30	566	9.57	0.284	10.5	DEC-09-80	27		SPECIAL STUDY
T030U30	532	9.57	0.284	10.5	DEC-09-80	28		SPECIAL STUDY
T031U40	545	9.94	0.900	33.3	JAN-19-82	7		SPECIAL STUDY
T032U40	552	11.8	0.797	29.5	JAN-26-82	7		SPECIAL STUDY
T001U50	539	10.4	2.91	108.	FEB-23-76	94		SPECIAL STUDY
T002U50	524	12.0	2.91	108.	MAR-11-76	726		SPECIAL STUDY
T003U50	541	11.4	2.42	89.5	FEB-25-76	7		SPECIAL STUDY
T004U50	541	9.01	2.91	108.	FEB-25-76	14		SPECIAL STUDY
T005U50	541	9.08	2.96	110.	FEB-25-76	21		SPECIAL STUDY
T006U50	509	12.2	2.92	108.	FEB-25-76	364		SPECIAL STUDY
T007U50	667	10.4	2.77	102.	MAY-10-76	1		SPECIAL STUDY
T008U50	564	10.3	2.80	104.	APR-28-81	21		SPECIAL STUDY
T009U50	560	11.7	2.82	104.	APR-28-81	21		SPECIAL STUDY
T021U50	532	11.4	3.55	131.	DEC-09-80	7		SPECIAL STUDY
T022U50	566	8.39	3.52	130.	DEC-09-80	8		SPECIAL STUDY

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T023U30 THRU T030U30 RECEIVED U-232 ONLY.
T031U40 THRU T032U40 RECEIVED U-233 ONLY.
T021U50 RECEIVED 103 KBQ/KG (2.78 UCI/KG, OF U-232 AND 37.4 KBQ/KG (1.01 UCI/KG) OF U-233.
T022U50 RECEIVED 102 KBQ/KG (2.76 UCI/KG) OF U-232 AND 37.0 KBQ/KG (1.00 UCI/KG) OF U-233.

B.26 ^{238}U, Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T001V01	567	11.3	0.00010	0.00370	NOV-16-76	2030		SPECIAL STUDY

B.27 X-Ray, Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	WEIGHT (KG)	INJECTED (UCI/KG)	INJECTED (KBQ/KG)	DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS	X-RAY EXPOSURE, R
T001XF	203				NOV-30-56	5775		SPECIAL STUDY	60
T002XM	201				NOV-28-56	4674		SPECIAL STUDY	90
T003XF	483				APR-11-60	5527		SPECIAL STUDY	82
T004XM	475				APR-11-60	3812		SPECIAL STUDY	68
T005XF	28				APR-04-60	5745		SPECIAL STUDY	84
T006XM	28				APR-04-60	121		SPECIAL STUDY	1.2

B.28 ^{210}Po, Test Studies

DOG NUMBER	INJECTION AGE (DAYS)	INJECTION WEIGHT (KG)	INJECTION INJECTED (UCI/KG)	INJECTION INJECTED (KBQ/KG)	INJECTION DATE INJECTED	POST INJECTION INTERVAL	DOSE TO SKELETON (GY)	COMMENTS
T001Z40	2501	12.3	3.39	125	JUL-12-84	470		SPECIAL STUDY
T002Z40	2495	10.9	3.37	125	JUL-12-84	243		SPECIAL STUDY
T003Z40	2465	12.1	3.18	118	APR-08-86	7		SPECIAL STUDY
T004Z40	2421	12.2	3.16	117	APR-08-86	28		SPECIAL STUDY

B.29 Ancillary Studies

DOG NUMBER	DAYS AGE AT DEATH	COMMENT
F001A00	1383	SPECIAL STUDY
F002A00	2492	SPECIAL STUDY, THYROIDITIS
M003A00	1451	SPECIAL STUDY
M004A00	3345	STATUS EPILEPTICUS
M005A00	3747	TRANSITIONAL CELL CARCINOMA (URINARY BLADDER), NEPHRITIS
M006A00	5266	HEMORRHAGE (BRAIN)
M007A00	3895	LYMPHOSARCOMA
M008A00	3745	PARALYSIS (NO SKELETAL TUMOR)
F009A00	3719	FIBROSARCOMA (SOFT TISSUE)
F010A00	2605	SPECIAL STUDY
F011A00	4198	MAMMARY ADENOCARCINOMA, PULMONARY THROMBOEMBOLISM
F012A00	4218	ARTHRITIS
F013A00	4527	SPECIAL STUDY
F014A00	3777	THROMBOEMBOLISM
F015A00	4874	TRANSITIONAL CELL CARCINOMA (URINARY BLADDER)
F016A00	4415	SPECIAL STUDY
F017A00	2145	TRAUMA
F018A00	5921	NEPHRITIS
F019A00	4166	MAMMARY ADENOCARCINOMA
F020A00	2464	SPECIAL STUDY
F021A00	5508	MAMMARY ADENOCARCINOMA, THYROID CARCINOMA
F022A00	4350	LYMPHOSARCOMA
M023A00	1741	THROMBOEMBOLISM
M024A00	3074	SPECIAL STUDY
F025A00	5645	ISLET CELL TUMOR, PNEUMONIA
M026A00	4132	PERITONITIS, PANCREATITIS
M027A00	2129	SPECIAL STUDY
M028A00	3113	SPECIAL STUDY
M029A00	5016	MELANOMA (MOUTH)
F031A00	5265	STATUS EPILEPTICUS
F032A00	1990	LYMPHOSARCOMA
F033A00	3283	AMYLOIDOSIS (KIDNEY), PULMONARY THROMBOEMBOLISM
F034A00	2584	SPECIAL STUDY
M035A00	529	SPECIAL STUDY
M036A00	1971	SPECIAL STUDY
M037A00	4091	SPECIAL STUDY
F038A00	3802	MAMMARY ADENOCARCINOMA
M039A00	4406	THROMBOEMBOLISM
M040A00	4666	EPIDERMOID CARCINOMA (MOUTH), PNEUMONIA
F041A00	4704	LEIOMYOSARCOMA (SPLEEN)
M042A00	1265	STATUS EPILEPTICUS
F043A00	3883	SPECIAL STUDY, REASSIGNED-SEE T018P5
F044A00	5016	ADRENAL CORTEX CARCINOMA
F045A00	6182	PNEUMONIA, SENILITY

B.29 Ancillary Studies (continued)

DOG NUMBER	DAYS AGE AT DEATH	COMMENT
M046A00		REASSIGNED, SEE T048R60
F047A00	1732	SPECIAL STUDY
F048A00	5076	PANCREATITIS
F049A00	4773	ISLET CELL TUMOR, HEMORRHAGE (BRAIN)
M050A00	2263	SPECIAL STUDY
F051A00	1089	SPECIAL STUDY
F052A00	509	SPECIAL STUDY
F053A00	5520	THYROID CARCINOMA
F054A00	3190	SPECIAL STUDY, PYOMETRA
F055A00	4563	NEPHRITIS
M056A00	701	VOLVUS, PERITONITIS
F057A00	4322	UNDIFFERENTIATED MALIGNANCY (ABDOMINAL CAVITY)
M058A00	767	SPECIAL STUDY
M059A00	567	SPECIAL STUDY
M060A00		REASSIGNED, SEE T071R50
M061A00	5511	RETICULOSARCOMA
F062A00	5348	THROMBOEMBOLISM
F063A00	4530	MAMMARY ADENOCARCINOMA, TRANS CELL CARCINOMA (URIN. BLADDER)
M064A00		REASSIGNED, SEE T045R30
M065A00		REASSIGNED, SEE T044R30
M066A00		REASSIGNED, SEE T040R10
M067A00		REASSIGNED, SEE T041R10
F068A00	4521	UNDIFFERENTIATED CARCINOMA (ABDOMINAL CAVITY)
F069A00		REASSIGNED, SEE T046R30
F070A00	5914	FIBROSARCOMA (SOFT TISSUE), NEPHRITIS
M071A00	1472	SPECIAL STUDY
M073A00	5695	DEGENERATION (ADRENAL GLAND), DIABETES MELLITUS
F074A00	5553	LYMPHOSARCOMA
M075A00	5283	THROMBOEMBOLISM
F076A00	5812	EPIDERMOID CARCINOMA (MOUTH)
F077A00	6047	RHABDOMYOSARCOMA, PAPILLARY CARCINOMA (OVARY)
F078A00	5110	HEPATIC CELL CARCINOMA
F079A00	4359	PNEUMONIA
F080A00	5419	LUNG CARCINOMA
F081A00	5921	LEIOMYOSARCOMA
M082A00	3627	LUNG CARCINOMA
F083A00	4988	INTESTINE SARCOMA
M084A00	5292	LYMPHOSARCOMA
M085A00	5498	CERVICAL SPONDYLOSIS
M086A00	498	SPECIAL STUDY
F087A00	4861	SPECIAL STUDY
F088A00		REASSIGNED, SEE T107W50
F089A00		REASSIGNED, SEE T074P40
F090A00		REASSIGNED, SEE T075P40

B.29 Ancillary Studies (continued)

DOG NUMBER	DAYS AGE AT DEATH	COMMENT
F091A00	4797	SPECIAL STUDY
F092A00	4799	SPECIAL STUDY
M093A00		REASSIGNED, SEE T076P40
F094A00		REASSIGNED, SEE T077P30
F095A00	4719	SPECIAL STUDY
F096A00	4373	HEMANGIOSARCOMA (SOFT TISSUE)
F097A00	4117	SPECIAL STUDY
F098A00	3752	MAMMARY ADENOCARCINOMA
F099A00	479	SPECIAL STUDY
M100A00	406	SPECIAL STUDY
M101A00	290	SPECIAL STUDY
F102A00	243	SPECIAL STUDY
M103A00	217	SPECIAL STUDY
M104A00	188	SPECIAL STUDY
F105A00	157	SPECIAL STUDY
F106A00	4324	SPECIAL STUDY
F107A00	4131	SPECIAL STUDY
F108A00	1969	ENCEPHALITIS
F109A00	2252	ENDOMETRITIS
F110A00		REASSIGNED, SEE T078P30
F111A00	2924	PNEUMONIA
F112A00	2942	SPECIAL STUDY
F113A00		REASSIGNED, SEE T123P20
F114A00	2591	SPECIAL STUDY
F115A00	2057	STOMACH CARCINOMA
F116A00		REASSIGNED, SEE F501P20+
F117A00		REASSIGNED, SEE F501R40+
F118A00		REASSIGNED, SEE F501P10+
F119A00		REASSIGNED, SEE F501P17+
F120A00		REASSIGNED, SEE F501P30+
F121A00		REASSIGNED, SEE F501R30+
F122A00		REASSIGNED, SEE F502P30+
F123A00	375	ACCIDENTAL STRANGULATION
F124A00		REASSIGNED, SEE F502P17+
F125A00		REASSIGNED, SEE F502P20+
F126A00		REASSIGNED, SEE F503P17
F127A00		REASSIGNED, SEE F503P20+
F128A00		REASSIGNED, SEE F502R40+
F129A00		REASSIGNED, SEE F503R30+
F130A00		REASSIGNED, SEE F504P1.7+
F131A00		REASSIGNED, SEE F502P1.0+
F132A00		REASSIGNED, SEE F501R5.0+
F133A00		REASSIGNED, SEE F503R4.0+
F134A00		REASSIGNED, SEE F503R3.0+

B.29 Ancillary Studies (continued)

DOG NUMBER	DAYS AGE AT DEATH	COMMENT
F135A00		REASSIGNED, SEE F502R5.0+
M136A00	3465	SPECIAL STUDY
F137A00		REASSIGNED, SEE F504R50+
F138A00		REASSIGNED, SEE F504P20+
F139A00		REASSIGNED, SEE F505P20+
F140A00		REASSIGNED, SEE F505P17+
F141A00	1830	PANCREATITIS
F142A00		REASSIGNED, SEE F503P10+
F143A00		REASSIGNED, SEE T176W30+
F144A00		REASSIGNED, SEE F504R40+
F145A00		REASSIGNED, SEE F503R50+
F146A00	3202	SPECIAL STUDY, PANCREATITIS
F147A00		REASSIGNED, SEE F506P17+
F148A00	1801	SPECIAL STUDY
F149A00	4317	SPECIAL STUDY
F150A00	4385	SPECIAL STUDY
F151A00	4205	SPECIAL STUDY
F152A00	568	SPECIAL STUDY
F153A00	4282	SPECIAL STUDY
F154A00		REASSIGNED, SEE F513R40+
F155A00	2931	SPECIAL STUDY, PANCREATITIS
F156A00	2406	NOSE ADENOCARCINOMA
F157A00	2603	SPECIAL STUDY
F158A00		REASSIGNED, SEE T242P30+
F159A00		REASSIGNED, SEE T243P30+
F160A00		REASSIGNED, SEE T211P20
F161A00	3926	SPECIAL STUDY (MAMMARY ADENOCARCINOMA)
F162A00	3926	SPECIAL STUDY
F163A00	1257	SPECIAL STUDY
F164A00		REASSIGNED, SEE T206P20
M165A00	92	SPECIAL STUDY
M166A00	388	SPECIAL STUDY
F167A00	369	SPECIAL STUDY
M168A00	517	SPECIAL STUDY
M169A00	513	SPECIAL STUDY
M170A00	510	SPECIAL STUDY
M171A00	95	SPECIAL STUDY
F172A00	518	SPECIAL STUDY
F173A00	89	SPECIAL STUDY
F174A00	94	SPECIAL STUDY
F175A00	520	SPECIAL STUDY
F176A00	521	SPECIAL STUDY
M177A00	3420	SPECIAL STUDY
M178A00	1186	SPECIAL STUDY

B.29 Ancillary Studies (continued)

DOG NUMBER	DAYS AGE AT DEATH	COMMENT
M179A00	4125	SPECIAL STUDY
F180A00	3653	SPECIAL STUDY
M181A00	1211	SPECIAL STUDY
M182A00	196	SPECIAL STUDY
M183A00	3064	SPECIAL STUDY
F184A00	184	SPECIAL STUDY
M185A00	524	SPECIAL STUDY
M186A00	189	SPECIAL STUDY
F187A00	93	SPECIAL STUDY
F188A00	193	SPECIAL STUDY
F189A00	262	SPECIAL STUDY
F190A00	372	SPECIAL STUDY
F191A00	176	SPECIAL STUDY
M192A00	91	SPECIAL STUDY
M193A00	369	SPECIAL STUDY
F194A00	371	SPECIAL STUDY
M195A00	362	SPECIAL STUDY
M196A00	1168	SPECIAL STUDY
M197A00	275	SPECIAL STUDY
F198A00	274	SPECIAL STUDY
M199A00	279	SPECIAL STUDY
M200A00	263	SPECIAL STUDY
F201A00	267	SPECIAL STUDY
M202A00	4150	SPECIAL STUDY
F203A00	3546	SPECIAL STUDY
M204A00	182	SPECIAL STUDY
F205A00	91	SPECIAL STUDY
F206A00	3759	SPECIAL STUDY, AMYLOIDOSIS (KIDNEY)
F207A00	3729	SPECIAL STUDY
M208A00	797	SPECIAL STUDY
M209A00	782	SPECIAL STUDY
M210A00	4403	SPECIAL STUDY
F211A00	2368	SPECIAL STUDY, STATUS EPILEPTICUS
F212A00		REASSIGNED, SEE T207P20
F213A00		REASSIGNED, SEE T208P20
F214A00		REASSIGNED, SEE T209P20
F215A00	3528	SPECIAL STUDY
F216A00	3334	MAMMARY ADENOCARCINOMA
F217A00		REASSIGNED, SEE F514R40+
F218A00	3910	SPECIAL STUDY (CHRONIC PANCREATITIS)
F219A00	3884	SPECIAL STUDY
F220A00	3836	SPECIAL STUDY
F221A00		REASSIGNED, SEE T212P20
F222A00		REASSIGNED, SEE T183W30

B.29 Ancillary Studies (continued)

DOG NUMBER	DAYS AGE AT DEATH	COMMENT
F223A00		REASSIGNED, SEE T142R50
F224A00		REASSIGNED, SEE T143R50
F225A00	623	SPECIAL STUDY
F226A00	616	SPECIAL STUDY
M227A00	557	SPECIAL STUDY
M228A00	553	SPECIAL STUDY
F229A00		REASSIGNED, SEE T139R30+
F230A00	1586	UNDETERMINED
F231A00		REASSIGNED, SEE T135R30+
F232A00		REASSIGNED, SEE T003Z40
F233A00	2657	SPECIAL STUDY
F234A00		REASSIGNED, SEE T137R3.0+
F235A00		REASSIGNED, SEE T141R30+
F236A00		REASSIGNED, SEE T004Z40
F237A00	2697	SPECIAL STUDY
F238A00		REASSIGNED, SEE T181W30
F239A00		REASSIGNED, SEE T184W30
F240A00		REASSIGNED, SEE T136R30+
F241A00	2456	SPECIAL STUDY
F242A00	2378	SPECIAL STUDY
F243A00		REASSIGNED, SEE T310P20
F244A00		REASSIGNED, SEE T182W30
M245A00	2067	SPECIAL STUDY
M246A00	2077	SPECIAL STUDY
F247A00	1397	SPECIAL STUDY
F248A00	1358	SPECIAL STUDY
F249A00	1344	SPECIAL STUDY
F250A00		REASSIGNED, SEE T186W30
F251A00	1307	SPECIAL STUDY
F252A00	1252	SPECIAL STUDY
F253A00	1275	SPECIAL STUDY
F254A00	1231	SPECIAL STUDY
F255A00	1300	SPECIAL STUDY
F256A00	1092	SPECIAL STUDY
F257A00	1078	SPECIAL STUDY
F258A00	1084	SPECIAL STUDY
F259A00	1152	SPECIAL STUDY
F260A00	1104	SPECIAL STUDY